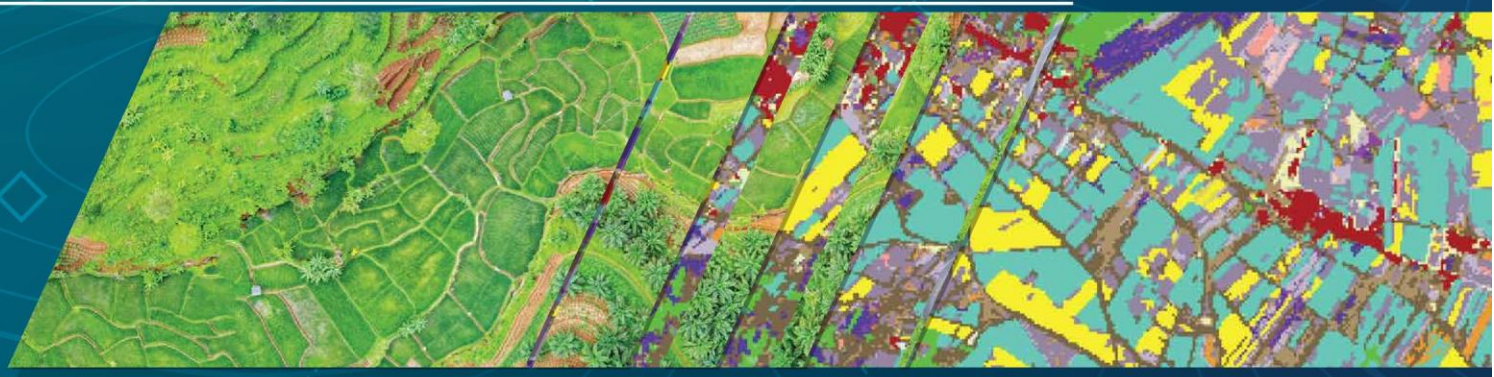
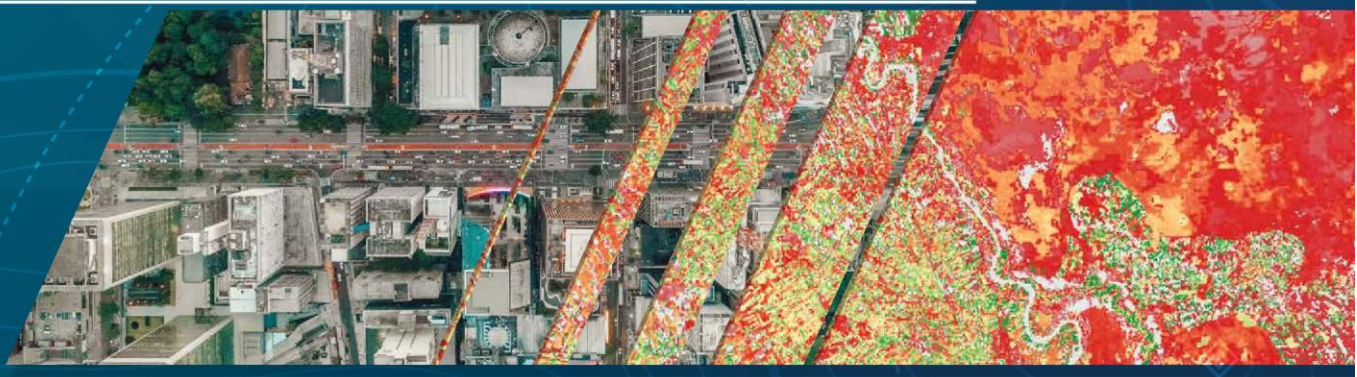
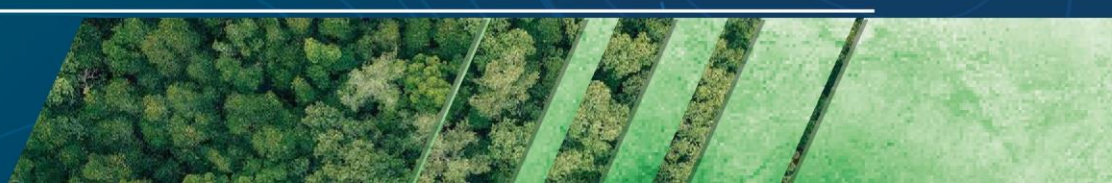
Food and Agriculture Organization of the United Nations
UNIVERSITY OF Southampton
STIIMA

The land characterization meta-language

A new approach to define the primary aspects of the land through the functional relationship of its biophysical and socioeconomic characteristics







The land characterization meta-language

A new approach to define the primary aspects of the land through the functional relationship of its biophysical and socioeconomic characteristics

Published by
Food and Agriculture Organization of the United Nations
and
University of Southampton
and
Institute of Intelligent Industrial Technologies, and Systems for Advanced Manufacturing - National Research Council
Rome, 2024

Required citation: FAO, UoS & STIIMA-CNR. 2024. *The land characterization meta-language – A new approach to define the primary aspects of the land through the functional relationship of its biophysical and socioeconomic characteristics.* Rome. https://doi.org/10.4060/cd0064en

ISBN 978-92-5-138637-8 [FAO]

Contents

Figures

Abbreviations

ALUM	Australian land use and management
APA	the American Planning Association
BAU	Basic Administrative Units
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GAEZ	Global Agro-Ecological Zoning
IGU	International Geographic Union
INSPIRE	Infrastructure for Spatial Information in Europe
ISO	International Organization for Standardization
ISIC	International Standard Classification for all Economics Activities
LC	land cover
LBCS	land-based classification standards
LCCS	Land Cover Classification System
LCML	land cover meta-language
LCHML	land characterization meta language
LU	land use
LUCM	land use coding manual
SDG	Sustainable Development Goals
STIIMA-CNR	Institute of Intelligent Industrial Technologies, and Systems for Advanced Manufacturing - National Research Council
TWG	Thematic Working Group
UML	Unified Modelling Language
UN	United Nations
UNEP	The United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNSD	United Nation Statistical Division
US	United States
USGS	United States Geological Survey
WLUS	World Land Use Survey

Acknowledgements

Sincere appreciation to the authors and contributors who have made this endeavour possible. Special thanks to Antonio Di Gregorio, Matieu Henry and Fatima Mushtaq from Food and Agriculture Organization of the United Nations (FAO); Charles Douglas O'Brien from IDON Technologies Inc; Nicola Mosca from Institute of Intelligent Industrial Technologies, and Systems for Advanced Manufacturing - National Research Council (STIIMA-CNR); and Chris Hill and John Latham from University of Southampton for their valuable contribution towards this publication.

Foreword

Comprehending the effects of human interventions on our constantly evolving landscapes relies on a thorough understanding of both land cover (LC) and land use (LU). These fields have been at the forefront of addressing critical questions regarding resource management, sustainable development, and environmental conservation. However, as our understanding of the complex interplay between natural and anthropogenic processes has grown, available data, information, and technologies have all critically increased. Therefore, the need for a common language and standardized approaches in the field of land characterization has become increasingly necessary.

The interconnected aspects of LC and LU are central to the quest for sustainability, resilience, and informed decision-making. Yet, over time, the boundaries between LC and LU have often blurred, making it challenging to convey their nuances effectively. This publication endeavors to shed light on the essential relationship between these two concepts and introduces a new meta-language for land characterization that captures this intricate connection.

This publication seeks to articulate and illuminate the intricate web of connections between LC and LU. This land characterization meta-language schema is rooted in the understanding that an effective and functional LC and LU relationship can only be established through a paradigm shift, which necessitates the creation of a unified modelling language (UML) schema.

FAO has been working closely at the global, regional, and national level with institutions, governmental sectors, and academia to ensure development, and implementation of standards using advanced technologies. In this dynamic era of technological advancement and global interconnectedness, the importance of standards in land characterization cannot be overstated. As we look to the future, the role of standards in ensuring data integrity and fostering collaboration will only become more critical.

We extend our sincere appreciation to the authors and contributors who have made this endeavour possible. We invite all who read this publication to embark on a journey of exploration and discovery, to embrace the concept of a unified meta-language for land characterization, and to realize the profound impact it can have on our collective efforts to preserve, manage, and enrich our lands.

Lifeng Li
Director, Land and Water Division, Food and Agriculture Organization of the United Nations

Prof. Justin Sheffield
Head, School of Geography and Environment Sciences, University of Southampton, United Kingdom of Great Britain and Northern Ireland

Lorenzo Molinari Tosatti
Acting Director, Institute of Intelligent Industrial Technologies, and Systems for Advanced Manufacturing - National Research Council (STIIMA - CNR) of Italy

Abstract

There is a clear relationship between land cover (LC) and land use (LU). In fact, many existing LU classifications are based on LC information and vice versa. In practice, in many instances LC and LU concepts are so closely interrelated that often the meaning of terms becomes interchangeable. The description of a portion of land includes both LC and LU information (described as the biophysical land components and the human activities that shape and/or modify them). In a modern and efficient system, one cannot substitute one for the other. However, the two are and must be well separated concepts. Therefore, an effective and functional relationship between LC and LU needs to be established formally.

This publication attempts to show this relationship. The title, land characterization meta-language (LCHML), is used in this paper to represent the combination of the description of the terms LC and LU. The LCHML includes both LC and LU and the bridging relationships between them. The land characterization meta-language schema follows the premise that an effective and functional LC and LU relationship can be built only with a change of paradigm creating a unified modelling language schema based on the three-way relationship between the biophysical cover, the activities being performed and the functions to which the land is devoted at a point in time.

1. Introduction

The utilization of land by man and the consequences of that utilization has interested people from time immemorial. From regional to national extents, land use (LU) is typically measured and mapped at a coarse spatial resolution (e.g. state or county level) and typically, for only broad categories of use (e.g. urban, agriculture etc.). There is no unified or detailed world-wide classification system which exists for LU. Some land cover (LC) maps depict developed LC types that are directly related to human activities. However, this information cannot represent the full extent and complexity of human use of the land. Therefore, there is a need for a systematic and detailed meta language for LU and LC that can act as a structure to describe a classification that is translatable between class structures.

As there is no agreement on any of the common classificatory principles, so the need for a unified and effective classification system for the temporal and spatial comparison of LU is widely recognized which can be used for a broad range of policy, land use planning and statistical purposes (Mucher *et al.* 1993). The higher hierarchical levels of global LU classification need to be unified and accepted worldwide. However, these LU classes also need quantitative class boundaries in order to make comparisons possible. Such a system should be able to re-examine and then harmonize existing LU datasets to make realistic comparisons within and between countries. And, to collect time series information with which to analyze the dynamics of LU changes and therefore, detect and predict trends.

There is a clear relationship between LU and LC. Many existing LU classifications are based on LC information and vice versa, or the classes are mixed; often even where separate maps are generated. The LU classification is also often assigned to areas demarcated by spatial units determined by the LC classes rather than parcels defined explicitly by LU. LC and LU are often used interchangeably but their actual meanings are quite distinct in nature. It is important to distinguish this difference between LCLU, and the information that can be ascertained from each to address applications and change assessments. Furthermore, whilst LC information/classes can be determined by remote sensed, observational approaches, LU information/classes cannot be directly observed in this way. One can state that LC is the result of LU at a certain moment in time. In this sense, LC is the direct visible consequence of certain LU activities humans conduct on the biophysical cover of the earth. LU is determined by human activities over certain periods of time, while LC is static in time. Therefore, an effective and functional relationship between LC and LU needs to be established and described formally. This publication attempts to show this relationship.

2. Land characterization meta-language - conceptual context

2.1. The domain of interest

An international agreement on the definition of LC and LU does not exist; however, this is much more relevant for LU because of the many different perspectives from which it can be categorized. The term LU has, therefore, different meanings across different disciplines and is consequently identified with a wide range of different parameters (for instance, the ones determined by natural, economic, institutional, cultural, and legal factors). However, these different perspectives are all valid. In this paper we will only address the ones directly linked to the broad concept of land. In this context LC is defined as: "the observed biophysical cover of the earth's surface" (FAO, 2000). In the same manner LU is a description of the socio-economic activity and function of an area of land. A standardized metalanguage for addressing land cover was established as an ISO standard in 2012. The combination of these two concepts here is termed land 'characterization', as the statement and process of describing land from a multi-dimensional perspective. A standard metalanguage to address land use and the combination of LC and LU is also required.

2.2. The historical context

United Nations (UN) agencies have long played an important role with respect to the efforts to develop standardized LC and LU classifications and data harmonization. One of the first attempts to create an International Standard Classification for all Economics Activities (ISCEA) was proposed by the United Nations Statistical Division (UNSD) early in 1948 with three major revisions in 1958, 1968, and 1989 (UN, 1989). The ISIC was an international reference for productive activities and its main purpose was to provide a set of activity categories that can be utilized for the collection and reporting of statistics according to such activities.

The International Geographic Union (IGU), an organization formally established in Brussels in 1922, played an important role in the development of LU classification. In 1949, the IGU established an ad hoc commission on World Land Use Survey (WLUS). During its mandate, the commission developed the first world-wide Land Use Legend (LUL) at 1:100000 scale.

The WLUS legend is, however, a mix of LC classes with LU functions. The legend was adopted later by a large number of countries at a national level. The work of the IGU continued with the establishment of another commission on agricultural typology that developed a system only for agriculture. The system was further refined by Kostrowiki (a formal member of the commission) to produce in 1983 the first map of agriculture types of Europe. The work continued until 1983 with the support of United Nations Educational,

Scientific and Cultural Organization (UNESCO) with the development of the first Land Use Classification System (LUCS) that also included non-agricultural classes. In 1976, the Food and Agriculture Organization of the United Nations (FAO) developed the Land Utilization Type (LUT) system in the framework for the land evaluation. This first attempt was followed by major revisions and improvements in the late 1980s. LUT have subsequently been incorporated into global modelling of agricultural features through the Global Agroecological Zoning (GAEZ). In this period, a series of FAO commissioned studies was undertaken as well as a collaboration with the United Nations Environment Programme (UNEP) (Mucher *et al.*, 1993; Whyatt *et al.* 1997).

In 1996, a collaboration of ITC/FAO/WAU produced the LU database that allowed the creation of user defined hierarchical structures of agricultural LU classes. All these efforts were undertaken in parallel with other international and national agencies that in the same period were following a series of different approaches to produce an internationally accepted land use classification. From 1969 to 1971, a study was made by the commission on Geographic Applications of Remote Sensing of the Association of American Geographer (GARSAAG), the results were published and further elaborated in 1976 by Anderson *et al.* (1976) to produce the first satellite remote sensing driven LC and LU classification. In 1999, the review and update of the United States (US) standard land use coding manual (LUCM) led to the initiative of the Land-Based Classification Standards (LBCS) (APA, 2001) coordinated by the American Planning Association (APA). Many other recent initiatives exist, such as the European Union (EU) Infrastructure for Spatial Information in Europe (INSPIRE) data specifications on LU. However, the need for internationally accepted reference LU classification and LU data harmonization is far from solved.

2.3. A change of paradigm for the categorization of land information

LC and LU information are both important parameters in most of the studies related to natural environment, ecosystem services and many other important disciplines. However, despite the importance and the many efforts toward data harmonization (especially for LC), there does not exist an accepted model on how to link and functionally correlate these two types of information. On the contrary, there is often a contamination of LC and LU terms in many LC nomenclatures (Anderson, Corine, etc.) and surprisingly also in some LU classification (United Nations Framework Convention on Climate Change (UNFCC), National land use database (Harrison, 2006)). Even when the two information types are kept correctly clearly distinct, such as in the EU INSPIRE spatial data infrastructure (European Commission, 2015), LUCAS European Communities 2003 (Lucas, 2003) no effort has been made to model/describe their functional relationship. However, the close relationship between LC and LU has been acknowledged for a long time, and there is a broadly accepted understanding that one needs to maintain a clear separation between these two aspects of the land.

The historical use of hybrid ontologies where LC and LU terms are interchangeable and coexist in the same system are not any more able to describe or explain this increasingly more complex relationship. In addition, analyzing these systems from a purely

information content perspective, it is evident that there may arise a confusion of specific information content. The description of a portion of land includes both LC and LU information (intended as the biophysical land components and the human activities that shape and/or modify them). In a modern and efficient system, one cannot substitute one for the other. Nevertheless, it is not efficient or correct to create independent LC and LU systems and later to try to build a kind of artificial connection between them. According to the authors, it is much more effective to develop a new logical framework that will be able to dynamically integrate and incorporate both LC and LU information.

Such a new proposed framework should not disregard the most recent technical advances that characterize modern ontologies such as the use of WOL (web ontology language), the Markup languages, UML etc., all systems that can help to integrate the information into machine readable format. This change of paradigm should define a modern system which must be:

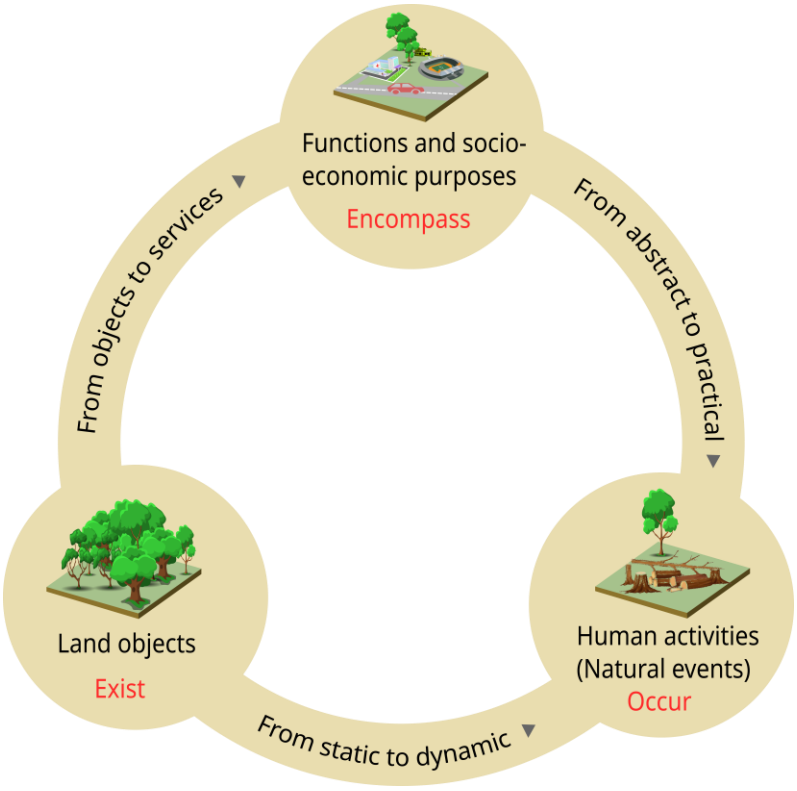
- simple, the determining factors or diagnostic criteria should be the most logical and accepted ones;
- stable, as much as possible, meaning that the diagnostic criteria are fundamental components of LC and LU over a longer period of time; and
- comprehensive, able to characterize LC and LU in all aspects.

Observing the land from this perspective it becomes evident a strong three-way relationship between land objects, land events and land functions (and/or socioeconomic purposes).

- **Land objects** are the biophysical aspect of the land. Basically, they are the static representation of the whole natural and artificial features characterizing a certain piece of land. In this sense they exist, at least in a certain precise time.
- **Land events** are the result of a dynamic characterization of the land. Some of them being natural (phenological activity of plants) and others characterized by the effect of human activities. They can be determined only over a certain period.
- **Land functions** are criteria related to the economic, cultural, and social value that a piece of land has. It is fully related to the behavioral interaction of individuals or a community of individuals.

Figure 1 shows this three-way relationship and relates it to the possible use of modern technologies for its assessment. There is a functional relationship between three basic elements which are: (1) the objects on the land that can be referred to “land cover”; (2) the human activities that occur on those objectives; and (3) the functions or the socioeconomic purposes that drives those activities.

Figure 1: Three-way functional relationship



Source: Author's elaboration.

2.4. Land cover meta-language

FAO with UNEP have a prominent role in the efforts to develop standardized LC and LU classification and data harmonization, especially with respect to LC. The adoption in the late 1990s of a parametric approach for the generation of an innovative Land Cover Classification System (LCCS) (Di Gregorio and Jansen 2000; Di Gregorio 2005) has changed the traditional paradigm within which to conceptualize a classification system. LCCS adheres to the concept that it is deemed more important to standardize the attribute terminology rather than the final categories. LCCS works by creating a set of standard diagnostic attributes, called classifiers, to create or describe different LC classes. The classifiers act as standardized building blocks and can be combined to describe the more complex semantics of each LC class in any separate application ontology.

The creation of or increase in detail in the conceptualization and description of an LC feature is not linked to a text description of the classifier but to the choice of clearly defined diagnostic attributes. Hence, the emphasis is no longer on the class name but on the set of clearly quantifiable attributes. This follows the idea of a hybrid ontology approach, with standardized descriptors allowing for heterogeneous user conceptualization. A further refinement of this method has resulted in the creation of the LCML (Di Gregorio, 2016a; Di Gregorio, 2016b). LCML is a fully object-oriented system represented with the most advanced modelling languages i.e. UML. This approach has become accepted as an international standard (ISO/TC 211, 19144-2:2012). The

development of the LCML has opened new perspectives for the generation, comparison, and harmonization of land cover information (Di Gregorio, 2018; Mosca *et al.*, 2020). The previous FAO LCCS (versions 1 and version 2) also followed the general approach represented in the LCML model. As of late, a new software, named, land characterization system (LCHS) has been launched and is accessible on the web (FAO, 2023).

LC can be represented by using simple atomic elements, using simple physiognomic criteria derived from vegetation studies widely accepted from a large domain of experts, rather than categories. Such elements e.g. tree, shrub, herb, building, etc. can be enriched by extra attributes and can be re-combined into complex categories as represented in different classical ontologies. LC is then represented in a database by a number of basic objects that can be further characterized by extra attributes defined as properties and characteristics. This approach is fully supported by the LCML in 2012 that became the standard ISO 19144-2 (UNFAO. 2000).

The LCML basic elements or objects, their relationships, inheritance and properties and characteristics associated to them, are formalized in a UML class diagram, also part of the standard. The LCML basic elements form a fixed vocabulary and can only be changed through the rigorous International Organization for Standardization (ISO) process for the revision of standards. These basic components are the stable basic vocabulary for describing any LC features. The vocabulary is fixed or can only be upgraded or modified after a specific ISO revision process that ensures backward compatibility, giving the entire system the necessary stability to support its role as a reference meta-language to harmonize various global legends or nomenclatures.

The standard stands on its own and can be implemented by any organization or nation that follows the standard, however, the FAO has developed a specific set of software tools to assist in the implementation. The UML diagram rules are instantiated using a specific software, Land Cover Classification System version 3 (LCCS3) (Di Gregorio, A. 2016a and 2016b) that allows the application of the model in an easy and user-friendly way.

2.5. A proposed new land use model

Despite the rapidly increasing success of new approaches in the domain of LC described in the previous chapter, the development of LU systems has remained quite resistant to radical innovations even in the most recent LU systems. Systems such as the US LBCS (APA, 1994) and the EU INSPIRE data specification on LU (INSPIRE, 2012), still are mainly based on traditional methods. A proposed approach for LU classification is possible and should take advantage of the experience gained during the development of the LCML model in the ISO process. The object-based hybrid ontology approach detailed in an UML class diagram could represent one of the most efficient ways to represent the complexity and variety of land features. This approach offers many advantages, of which the following are fundamental:

- 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 a more efficient way to represent complex land dynamics.
- The system is flexible, coping well with the advance of science in many different sectors, for instance, the use of markup languages (XSD, XML) to instantiate the information content.
- Because the LU system component is built up with same object-oriented logic of the 19144-2 LCML, it is a straightforward and effective way to model a functional relationship between the land biophysical component with the functions and activities, as proposed in the previous chapter (Figure 1).

2.6. Fundamentals for a new land cover and land use meta language

The creation of this new conceptual approach should consider as already done for the LCML the following:

- A meta language deals with the structuring of a specific knowledge domain to create consistency and stability in communication between the users. Therefore, its main function is the capability to be a valid reference system for a larger community of the users.
- Classifications are dynamic by nature and definitions can change over time, influenced by the prevalence of other cultures and new scientific advances. It should be recognized that no classification system can fully reflect either the social or the natural world comprehensively and accurately. There are and will always be multiple ways to conceptualize and communicate knowledge, thus there is an inherent ambiguity in any categorization. Therefore, it is of paramount importance that the creation of a structured reference system able to collate or harmonize different perspectives with which the different aspects of the land are classified.
- The only way to try to create consistency in this complex and dynamic domain is through the creation of a meta-language that defines the framework of elements and rules with which any user can define their own specific ontology.
- The system should be documented through a rigorous definition of a generative grammar explicated using, first, a graphic modelling language, UML class diagram, then reported in an XSD language for easier and unambiguous utilization of the rules in other application domains.
- The meta language should support 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.

2.7. Characteristics of the proposed meta-language

The acronym land characterization meta language (LCHML) is used in this publication to represent the combination of the description of the terms LCLU. Different groups may consider that LC and LU are under the responsibility of different organizations. From a management point of view this might be true, but when one creates a structure that describes the major aspects of "land" it is necessary to build a logical bridge. The LCHML includes both LC and LU and the bridging relationships between them.

There is another aspect of land which is the legal rights associated with land such as ownership and restrictions legally imposed on that land. This is expressed in a separate ISO standard, the ISO 19152 series, which describes the rights, restrictions, responsibilities, and associated parties that apply as special legal or official attributes to basic administrative units (BAU). These units are composed of multiple features, where a geographic feature is equivalent to a land object. In terms of the ISO TC211 reference model these features are representations of real-world phenomena (ISO, 2014).

2.8. Proposed structure for the land characterization meta-language

Following is the list of defining criteria upon which the LCHML is based:

- The LCHML should be able to unify and create a functional link between LC and LU. This functional link is the maximum expression of the descriptive power of the system. The resulting categories are, therefore, expressing a comprehensive information called land characterization. This efficient representation of a specific land situation will be a functional base for further elaboration to define more specific functionalities such as ecosystem services, farming systems, and so on.
- The LCHML is formed by two parallel but fully linked schemas for LC and LU representation.
- The two schemas are linked to each other with specific functional relations that will allow a high level of flexibility on the representation of LC and LU conditions.
- The overall LCHML will allow users to generate just a full LC legend, a full LU legend or when needed a functional integration of the two.
- The LC schema of the system is directly derived from the LCML.
- The LU schema of the system is characterized by a combination of two major LCHML elements i.e. functions and activities.
- The system will allow a very detailed and synergic combination of these two LU elements.

- The LU elements characterizing the LU schema are compatible with most of the diverse existing systems.
- The categories generated by the systems are not the usual categories defined by a name and in some cases by a text description but more of a sub model.
- It is more efficient and in line with the progress of modelling science to represent the complexity and dynamism of a specific area with a model rather than just a class name.
- The categories (models) generated by the system will be fully compatible with the most advanced techniques of data handling and interrogation. This will make the comparison, harmonization, restructuring, and analysis of the resulting data descriptions more compatible with an automatic, machine-oriented, highly interactive, and functional process.

2.9. Establishment of an ISO standard for land use and land characterization

The work on land characterization done by the FAO was submitted to ISO as part of the review and revision of the ISO 19144-2 - Land cover meta-language (LCML) standard in 2018. ISO then performed a preliminary (Stage 0) study on how to address Land Use in the context of the ISO TC211 series of Geographic information classification standards. This resulted in the establishment of a new project ISO 19144-3 Land Use Meta Language which incorporates the bridge between LCLU. This work in ISO is ongoing and is currently under committee discussion. The technical details described in the following section of this document represent the structure proposed to ISO. In the technical debates and input from many nations some elements may likely change. This document is not trying to describe the proceedings through the standardization process. It describes the status of the concept as proposed to ISO.

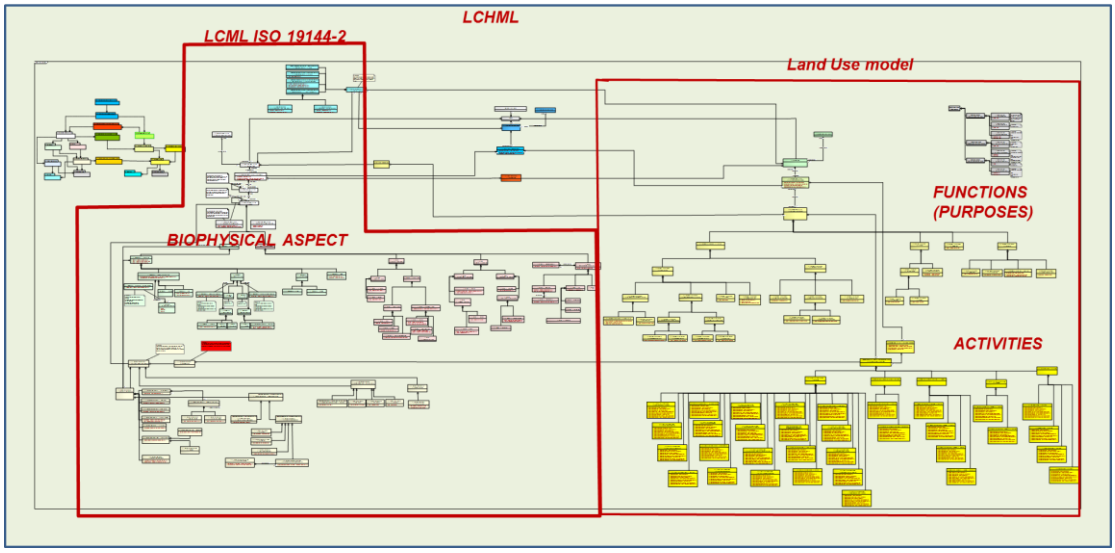
3. Land characterization meta-language - technical context

3.1. Land characterization meta-language schema overview

The LCHML schema follows the premise that an effective and functional LC and LU relationship can be built only with a change of paradigm creating a schema based on the three-way relationship of the biophysical aspect of the land, the human activities being performed on it and the function to which a land is devoted to. Therefore, the schema is divided into two major components (Figure 2):

- biophysical aspect of the land, and
- functions to which a land is devoted to and the activities that are taking place on it.

Figure 2: LCHML schema showing two major sections



The two sections are closely interconnected to assure an effective and functional relationship of the different language elements (Figure 2). The first part, biophysical aspect, is entirely derived from ISO 19144-2 LCML model. The model in its overall structure has remained unmodified to assure complete compatibility with the FAO - ISO joint standard. Only the list of characteristics has been adjusted. Some attributes present in the original LCML characteristic list were in effect qualities stating more human activities rather than biophysical aspects. This was done with the idea that with an increase of element characteristics some LC class

could describe some LU information. With the new expanded LCHML schema, this is not necessary anymore because a new section of the schema is dedicated to the description of LU. Therefore, the characteristics in the biophysical part of the schema now fully represent only the physiognomic or structural aspects of the language elements, while all the aspects related to human activities are shifted into the LU section. The geometric elements that may be used are defined by coverage geometry, and may be coverage of polygons, grids of various types or even point clouds representing samples. These are the same for LC or LU.

The full description of the biophysical component of the model is fully illustrated in the ISO 19144-2 document and in the FAO LCML technical manual (Di Gregorio, A. 2016a). The complete description of the LU component is described in Section 3.2. The model ensures a fully functional inter-connection of the two components. In fact, they are not separate entities but must be considered as a completely integrated system when used together to describe land. Overview of the different LCHML packages and their functional relationship is available in Figure 3. Whereas Figure 4 shows the main relationship that connects LC and LU elements.

To allow this integration the model provides many different interconnections which are as follows:

- **LC and LU relationship**: This relationship is the most important correlation tool that assures a fully functional relationship between an extensive biophysical and LU characterization of the land. The tool utilizes three different relationship types which are described below:

  Functional elements relationship models the functional relationship between the physiognomic or structural components of the schema with the function or activities. The relationship types can be chosen between:

  - **primary:** a direct and unique relationship exists between one physiognomic or structural component and one function (with related activities);
  - **dominant:** a relationship exists and is dominant with respect to others but is not unique;
  - **secondary:** a relationship exists but is not dominant (another dominant relationship exists); and
  - **limited:** the relationship is weak and not complete (limited to a few situations).

  Relationship temporal aspect models the temporal aspect of the relationship. The list of types is composed of the following:

  - **total:** the relationship is consistent all the time;
  - **time sequence (linear) depending:** the relationship is partial for some laps of time; and
  - **cyclic:** the relationship is regularly repeated over time.

Time length describes the link with type 2 and describes the length of time with different options (days, weeks, months, years).

LC and LU can be described independently or in combination. There are five cases:

- **Pure LC description:** This characterization is purely based on the use of the physiognomic or structural component of the land objects.
- **LC description with extra LU attributes:** In this case, the physiognomic or structural characterization of the land objects is enriched with functions and/or activities incorporated from the LU component. This is the common case of many of the existing legends that are mostly land cover with some land use elements included.
- **Pure LU description:** This characterization uses both LU functions and activities but does not describe the LC.
- **LU description with extra LC attributes:** In this case, the combination of LU functions and activities is enriched through the inclusion of some attributes reporting on the physiognomic and structural component.
- **Functional LC and LU description:** This provides a complete and functional integration of physiognomic and structural elements with LU functions and activities.

Descriptive examples, showing how a typical parkland agroforestry area in sub-Saharan Africa can be represented under these five cases, is provided in Appendix D.

Figure 3: Overview of the different LCHML packages and their functional relationship

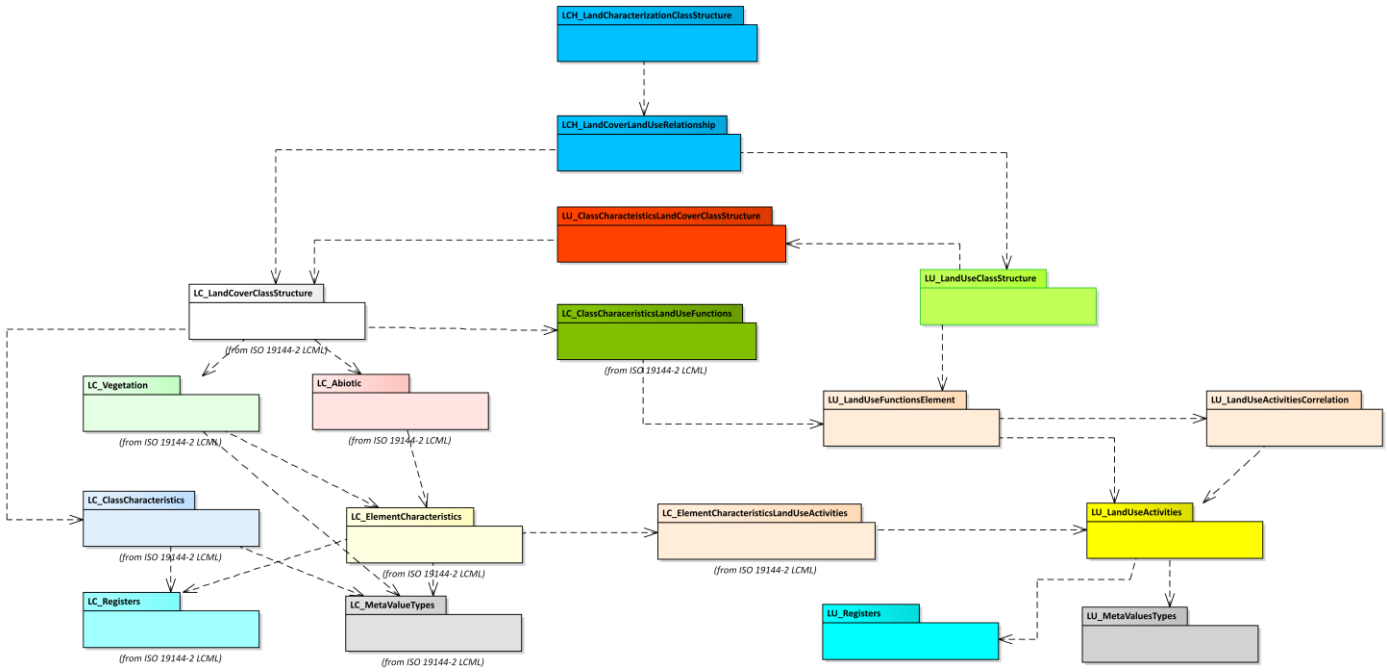
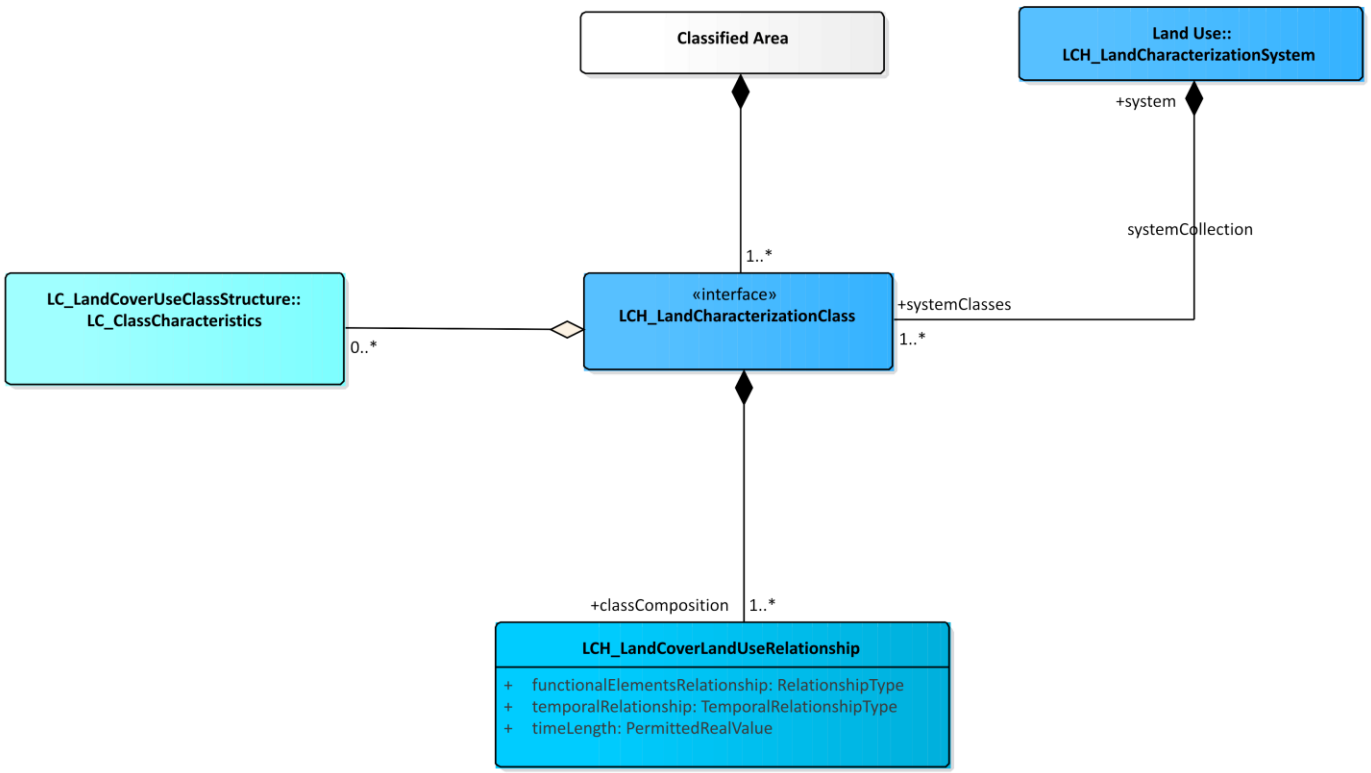


Figure 4: Main relationships that connects LC and LU elements



3.2. Land use component description

The LU component of the schema is based on a functional interaction between functions and activities which are as follows:

- **functions:** refers to the economic purpose or establishment type applied inland; and
- **activities:** refers to what takes place in physical or observable terms on the land defined under a specific function.

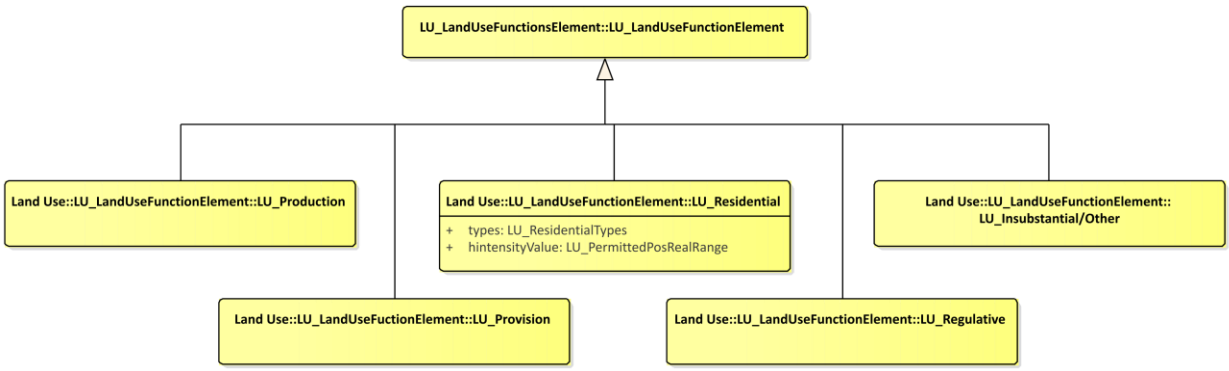
3.2.1. General overview of the functions

Five main functions are listed, each of which is sub-divided in different sub-functions. Because in most cases the land is defined by multi-functions, the single function elements are linked between themselves with a specific tool called functions element arrangement. The main five functions (Figure 5) are explained below:

- **Production:** the process of growing, harvesting, or making goods. It refers both to the growing of plants or animals and to the process and methods used to transform tangible raw materials into goods.
- **Provision:** the action or process of providing or supplying intangible products for other businesses or consumers. It refers to the provision of services, utilities, transport, or logistics.
- **Residential:** an area used mainly for housing, including both single and multi-family houses when not linked to direct and secondary production.
- **Regulative:** an area under specific normative rules (controlling, directing or managing) or principles including both conservation or protection of environmental areas, conservation or protection archeological sites, restriction rules to access particular areas.

  Note that the detailed rights, restrictions and responsibilities and parties associated with a regulative function may be described separately in an external legal document or in accordance with the Land Administrative Domain Model (LADM) specified in the ISO 19152 series of standards.
- **Insubstantial:** not evident, irrelevant, or negligible use.

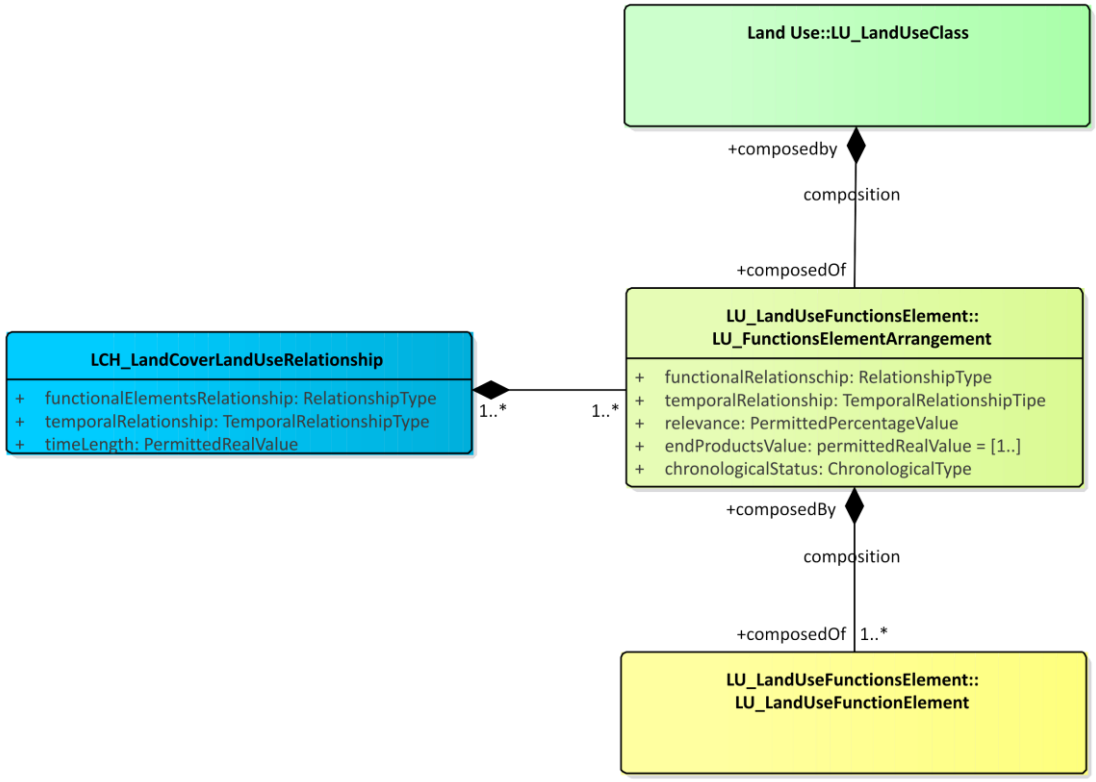
Figure 5: The main five functions



The functions are arranged together in a specific tool, called the functions element arrangement (Figure 6). The tool is composed of five sub types:

- **Functional relationship:** models the functional relationship between the different functions. Three types of functional relationship are possible i.e.
    i. dominant "a relationship exists and is dominant with respect to others but is not unique",
    ii. secondary "a relationship exists but is not dominant (another dominant relationship exists)", and
    iii. equivalent "a relationship exists with the same functional weight".
- **Temporal relationship:** models the temporal relationship between the different functions. Three types of functional relationship are possible i.e.
    i. coexistent "when they co-exist in the same time",
    ii. sequential "when there is sequential order", and
    iii. cyclic "when a specific sequence is repeated during a specific time".
- **End product value:** models the monetary value (as end product) of each function.
- **Relevance relationship:** models the relative weight of the functions between themselves.
- **Chronological status:** models the chronology of each function. It is divided into three types i.e.
    i. current,
    ii. former, and
    iii. forthcoming.

Figure 6: The different functions element arrangement types

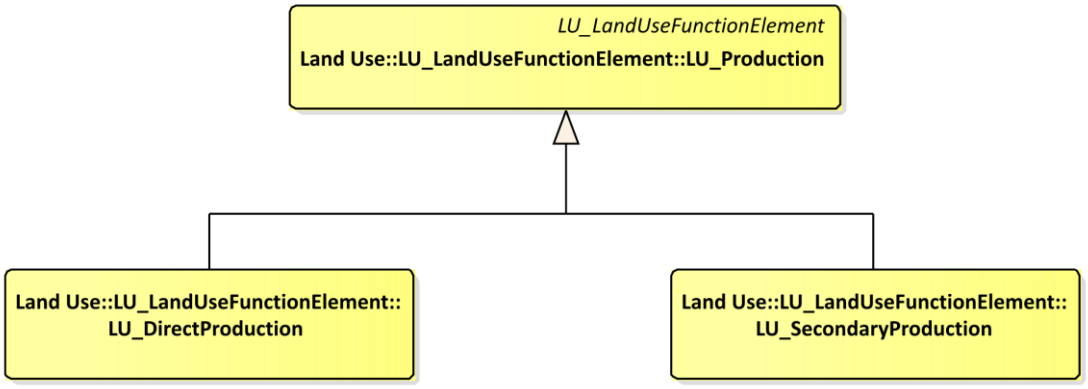


The production functions

The production function is divided into the two subcategories (Figure 7) below:

- **Direct or primary production:** the production of basic material or crops (see Appendix A for complete definition).
- **Secondary production:** manufacturing of goods (see Appendix A for complete definition).

Figure 7: First subdivision of production function in UML schema



The **direct production** is further divided into five different subcategories:

- **Terrestrial food, fiber, and fodder-related production** refers to the production of crops and animal products for food consumption and commercial purposes (see Appendix A). The function is further sub-divided into two different categories:

    1. **Plant agriculture:** refers to the growing of crops both in open fields and greenhouses. The function is defined by three different plant agriculture types i.e. exploitation, intensity, and scale.

    2. **Animal farming:** refers to the branch of agriculture related to animals raised for food consumption or other products.

- **Inland water or Marine food production** refers to the fishing or aquaculture both on inland water and sea (see Appendix A). It is further divided into:

    1. **Inland water aquaculture and "natural" fish harvest:** the further division is between aquaculture and fishing.

    2. **Marine aquaculture and "natural" fish harvest:** the further division is between aquaculture and fishing.

- **Natural products gathering** refers to the collection of natural products like hunting animals, collection of wild non-wood forestry products, etc. (see details in Appendix A). It is further divided into:

    1. **Terrestrial natural product gathering** refers to the gathering on terrestrial environment and is further subdivided into hunting and natural products piking.

    2. **Inland water and marine natural product harvesting** refer to the gathering on inland water or sea and is further sub-divided into inland water product harvesting in marine water product harvesting.

- **Forestry** is the practice of planting, managing, and caring of areas with trees defined as forest. Additional forestry types are listed and described in Appendix A.

- **Extraction** is the extraction of minerals and materials present in nature as solid, liquid or gas (see Appendix A). It is further sub-divided into:

    1. **Hard material extraction** contains three different types which are: position, mining types and material types.

    2. **Oil gas extraction** refers to the extraction of liquid and/or gass materials. It is further defined by two different types i.e. extracted material types and extraction types.

Figure 7 and Figure 8 show the division of the direct production in the schema.

Figure 8: Division and subdivision of direct production - Part A

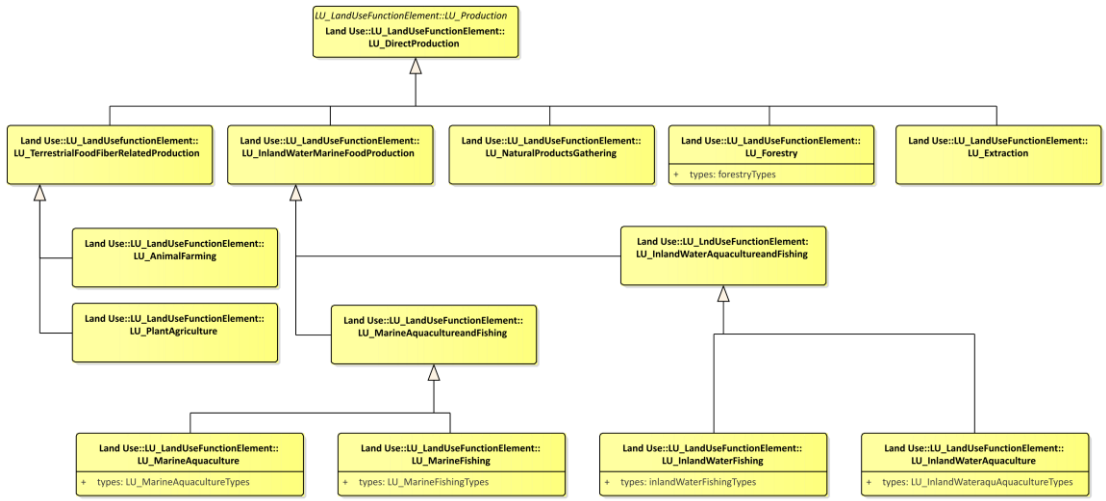
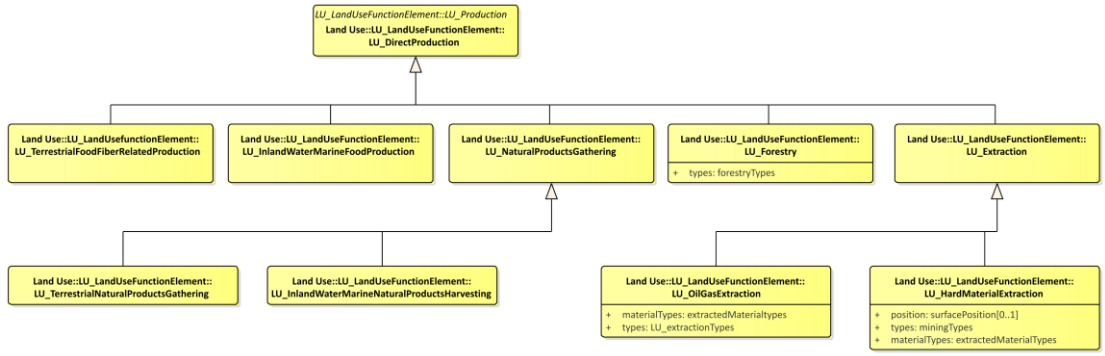


Figure 9: Division and subdivision of direct production - Part B



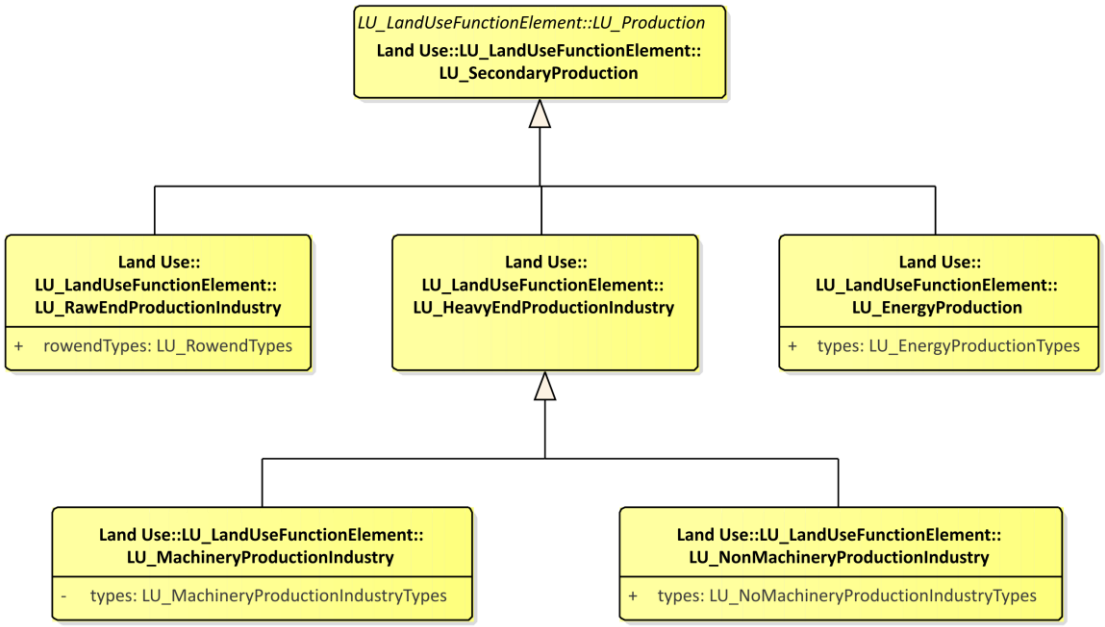
The **secondary production** (Figure 10) is further divided into three sub-divisions (see full list of types in Appendix A) described as follows:

- **Raw end production industry** contains all the industrial activities that are devoted to the transformation including packaging of the output 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.

- **Heavy end production industry** contains all the industrial activities that are devoted to the transformation of raw manufactured products into machinery and other heavy materials. It is further divided into machinery and non-machinery products.
- **Energy production** areas that are used to produce any form of energy including electric, fuel, gas, biogas, nuclear, etc.

Figure 10: Division and subdivision of secondary production in schema

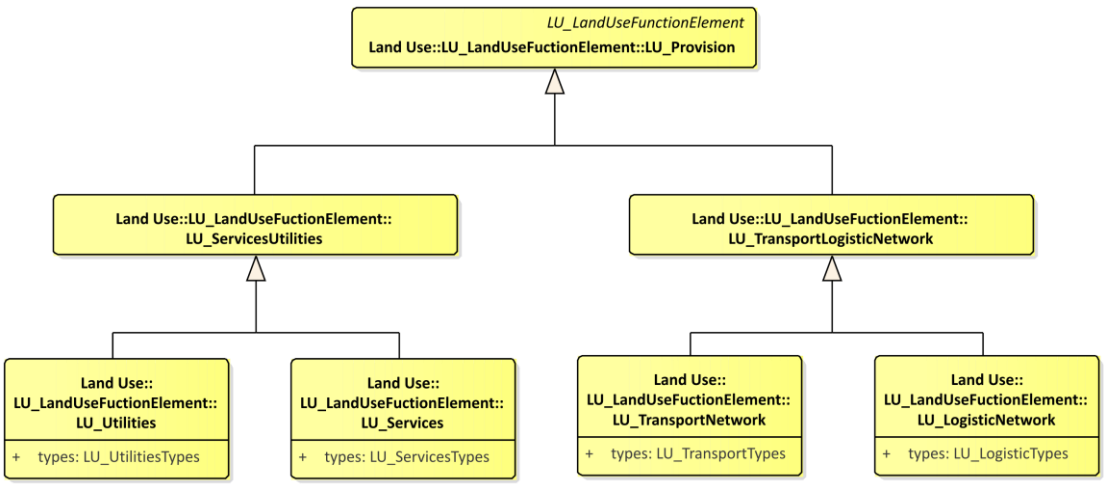


The provision functions

The Provision function (Figure 11) is subdivided in two major groups:

- **Services and Utilities** refers to all types of services including commercial, financial, commercial, cultural, recreational etc. and utilities including infrastructures related to energy distribution services, water distribution, sewage treatment etc. This sub-function is further divided into sole services and sole utilities. The related types are fully listed in Appendix A.
- **Transport and Logistic** refers to all types of infrastructures related to transport and logistics. This subfunction is further sub-divided into sole transport and sole logistics. The related types a fully listed in Appendix A.

Figure 11: Division and subdivision of provision utility in the schema

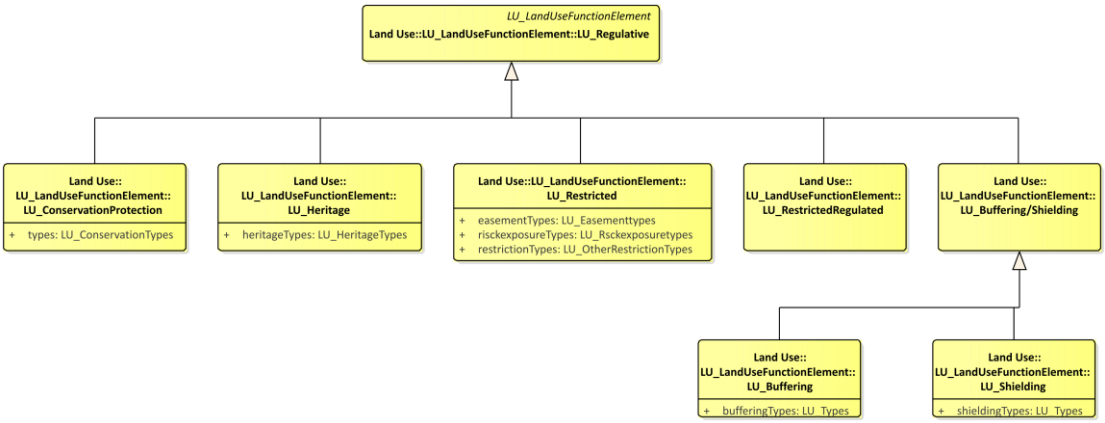


The regulative function

The Regulative function (Figure 12) is subdivided into four major groups:

- **Conservation or Protection** areas under specific conservation and/or protection rules. The complete list of related types is in Appendix A.
- **Heritage** areas having cultural, historical significance and therefore requiring some form of protection. Complete list of related types is in Appendix A: Functions.

Figure 12: Division and subdivision of regulative function in the schema



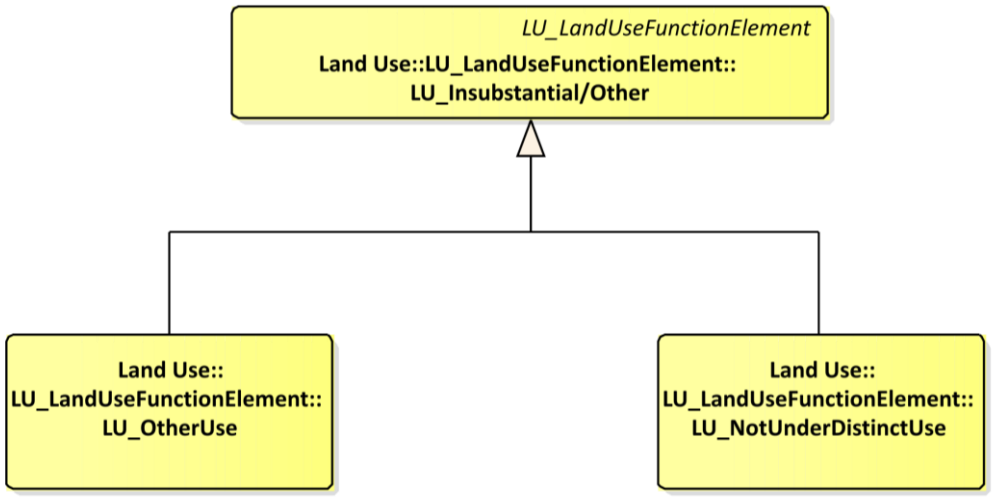
- **Restricted** areas where the access is restricted due to some specific hazard exposure including technological, natural etc. Complete list of related types can be seen in Appendix A.

- **Buffering and shielding** controlled zones designated to defend or protect from specific hazard including flooding, contamination etc. These zones are further divided into buffering and shielding. The related types are listed in Appendix A.

Insubstantial function

Insubstantial and other function (Figure 13) is further subdivided into other and not under distinct use.

Figure 13: Subdivision of the insubstantial function in the schema

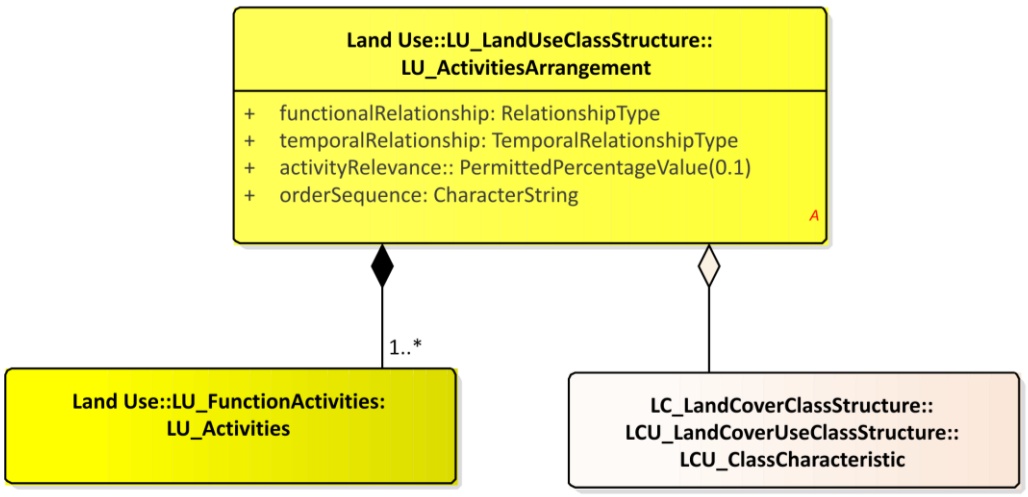


3.2.2. The activities for main functions

A list of activities is defined for each of the main functions. The activities are correlated to the function element through the activity arrangement tool. The activity arrangement tool is defined by four different types (Figure 14):

- **Functional relationship** models the functional relationship of the activities belonging to each activity function group. It is generated by three types which are dominant, secondary, and equivalent.
- **Temporal relationship** models the temporal relationship between the activities belonging to each activity function group. It is generated by three types i.e. coexistent, sequential, and cyclic.
- **Activity relevance** models the significance of the activities of each function with a range from 1 to 10.
- **Order sequence** models the logical succession of each activity with each other.

Figure 14: The LCHML element activity arrangement in the model



3.2.3. Specific operations for the activities

The activities are further modelled in specific operations or processes that are defined as procedures for the transformation of resources or data input into desired goods, services, or results. For each operation type (or subtype) a list exists and can be consulted in Appendix A. Each operation (or suboperation) is further defined by a series of operation element types as:

- **Operation handling** describes the tools used to perform a specific operation (or suboperation). Each operation (or suboperation) type has a list of tools that is enumerated in Appendix A.
- **Operation duration** determines the duration of a specific operation.
- **Operation starting date** determines the date on which a specific operation (or suboperation) starts.
- **Operation order sequence** determines the sequence of the different operations (or suboperations).
- **Operation functional relationship** determines the functional correlation between the different operations. It is divided into three types i.e. dominant, secondary, and equivalent.
- **Operation relevance**: determines the relevance of a specific operation in relation to the others. The value is given within a range from 1 to 10.

4. References

APA. 2001. *Land – Based Classification Standards, LBCS project.* American Planning Association. https://www.planning.org/lbcs/

Anderson, J.R., Hardy, E.E., Roach, J.T., Witmer, R.E. 1976. *A land-use and land-cover classification system for use with remote sensor data.* Geological Survey Professional Paper No. 964. U.S. Government printing office, Washington, D.C.

ALUM. 2016. *Management Classification Version 8.* Canberra, Australia: Department of Agriculture and Water Resources, Australian Bureau of Agricultural and Resource Economics and Sciences. https://www.agriculture.gov.au/abares/aclump/land-use/alum-classification

Baxter J. T., and Russell L. D. 1994. *Land use mapping requirements for natural resource management in the Murray-Darling Basin*. Murray-Darling Basin Commission.

Baulies, X., Szejwach, G., & LUCC Data Requirements Workshop. 1998. *LUCC data requirements workshop: Survey of needs, gaps and priorities on data for land-use/land-cover change research, Barcelona, 11-14 November 1997.* Barcelona, Spain: Institut Cartografic de Catalunya.

CEC. 1993. Nomenclature des activités de la communauté européenne (NACE). Première révision. Règlement 761/93 du Conseil. Commission of the European Communities, Brussels.

Di Gregorio, A. 2018. *Object Based Similarity Assessment Method of FAO – LCML originated LC data bases.* FAO internal report.

Di Gregorio, A. 2016a. *LCCS3 tutorial*. FAO Rome.

Di Gregorio, A. 2016b. *LCCS/LCML theoretical concept.* FAO Rome.

Di Gregorio, A. O'Brien, D. 2013. *Overview of Land Cover Classifications and their Interoperability.* Remote Sensing of Land Cover and Land Use 425 pp. Taylor & Francis Series in Remote Sensing Applications.

Di Gregorio, A. 2005. *land Cover Classification System (LCCS) version 2: Classification Concepts and User Manual.* FAO, UNEP.

Dolman, A.J., Verhagen, A., Rovers, C.A. (Eds.). 2003. *Global environmental change and land use.* Kluwer Academic Publishers, Dordrecht.

Dudley, N. 2008 and 2013. *Guidelines for Applying Protected Area Management Categories.* Gland, Switzerland. https://portals.iucn.org/library/sites/library/files/documents/pag-021.pdf

Duhamel, C. 1998. *First approximation for a land-use classification.* CESD-

Communautaire, Luxembourg. FAO commissioned study.

FAO. 2023. *Land Characterization System Software.* https://lcs.fao.org/ (November 9, 2023).

Herold, M. Di Gregorio, A. 2012. Evaluating *Land Cover Legends Using the UN Land Cover Classification System pp 65-89 Remote Sensing of Land Use and Land Cover 425 pp.* Taylor & Francis Series in Remote Sensing Applications.

Herold, M. Di Gregorio, A. 2006. *Evolving Standards in Land Cover Characterization*. pp 157-168. Journal of Land Use science

ECE-UN. 1989. *Proposed ECE standard international classification of land use.* Economic Commission for Europe of the United Nations, Geneva.

EUROSTAT. 2001. *Land-use/cover area frame statistical survey (LUCAS). Version 1.0.* Eurostat, Luxembourg. Rome.

IGU. 1976. *World land-use survey. Report of the Commission to the General Assembly of the International Geographic Union.* Geographica Helvetica No. 1. Pp. 28.

Jansen, L.J.M. & Di Gregorio, A. 2003. *Land-use data collection using the "Land-cover Classification System" (LCCS): results from a case study in Kenya.* Land Use Policy 20(2): 131-148.

Jansen, L.J.M. & Di Gregorio, A. 2004. *Obtaining land-use information from a remotely sensed land-cover map: results from a case study in Lebanon.* Int. Journal of Applied Earth Observation and Geoinformation 5: 141-157.

Kostrowicki, J. 1983a. *Land-use survey, agricultural typology and land-use systems: introductory remarks.* Rural Systems, Vol. 1 No. 1.

Kostrowicki, J. 1983b. *Land use systems and their impact on environment. An attempt at a classification.* Advances in Space Research, 2(8), 209-215. https://doi.org/10.1016/0273-1177(82)90242-3

Kostrowicki, J. 1992a. *A hierarchy of world types of agriculture. In New Dimensions in Agricultural Geography.* Vol. I: Historical Dimensions of Agriculture, N. Mohammed (Ed.), pp. 163–203. New Delhi, India: Vedams Books International.

Kostrowicki, J. 1992b, *Types of agriculture map of Europe: concept, method, techniques. In New Dimensions in Agricultural Geography.* Vol. I: Historical Dimensions of Agriculture, N. Mohammed (Ed.), pp. 227–249. New Delhi, India: Vedams Books International.

McConnell, W.J. & Moran, E.F. 2001. *Meeting in the middle: the challenge of meso-level integration. An international workshop on the harmonization of land-use and land-cover classification.* LUCC Report Series No. 5. Anthropological Center for Training and Research on Global Environmental Change - Indiana University and LUCC International Project Office, Louvain-la-Neuve

Mucher, C., Stomph, T. J., & Fresco, L. O. 1993. *Proposal for a global land use classification*. Final Report LUIS FAO, ITC and WAU, Rome, Enschede and Wageningen. https://edepot.wur.nl/296827

Mosca, Nicola *et al.* 2020. *Object-Based Similarity Assessment Using Land Cover Meta-Language (LCML): Concept, Challenges, and Implementation*. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 13: 3790–3805.

Remmelzwaal, A. 1989. *Classification of land and land use.* First approach. Internal working paper. FAO, Rome.

Sokal, R. 1974. *Classification: purposes, principles, progress, prospects.* Science, Vol. 85 (4157): 1115-1123.

UN. 1989. *International standard classification of all economic activities (ISIC).* Third revision. United Nations Statistics Division, Statistical Classifications Section, New York.

UN. 1998. *Central product classification (CPC).* Version 1.0. United Nations Statistics Division, Statistical Classifications Section, New York.

FAO. 2000. *Land Cover Classification System (LCCS). Classification concepts and user manual for software version 1.0.* By A. Di Gregorio and L.J.M. Jansen. Rome, ISBN 92-5-104216-0.

Wyatt, B.K., Billington, C., De Bie, K., De Leeuw, J., Greatorex-Davies, N., & Luxmoore, R. 1997. *Guidelines for land-use and land-cover description and classification.* ITE/WCMC/ITC/UNEP/FAO. Internal unpublished working document. ITE, Monkshood, UK.

Wyatt, B.K. & Gerard, F.F. 2001. *What's in a name? Approaches to the inter-comparison of land-use and land-cover classifications.* Strategic landscape monitoring for the Nordic countries, TemaNord 2001:523. Nordic Council of Ministers, Copenhagen.

Appendix A: Functions

The main five function definitions are as follows (these definitions are not static and can be further improved):

- **Production** is 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 aim of this sector is to transform natural resources into primary products.
- **Provision** is the action or process of providing or supplying intangible products for other business or consumers. It refers to the provision of services, utilities, transport or logistics. It includes both private and public facilities where services, utilities, transport, and logistics take place.
- **Residential** is an area where housing of people predominates. It includes a large variety of housing types such as single or multi-family houses, mobile homes, etc.
- **Regulative** is an area under specific normative rules including controlling, directing, or managing or principles including both conservation or protection of environmental areas, conservation or protection of archeological sites, restriction rules to access particular areas.
- **Insubstantial** not evident, irrelevant, or negligible use.

Definitions for the **production** sub-functions are as follows:

1. **Direct production** is the production of basic material or crops instead of products made from them. This sector transforms natural resources in both materials directly consumed by end users or raw materials that are transformed by other industries (food, metal, wood, etc.). The main sectors are plant agriculture, animal husbandry, agroindustry, fishing forestry, and mining activities. Industries for packaging, purifying, or processing primary products are included in this class, especially the ones related to agriculture.
    - **Terrestrial food and fiber production is** the practice of crops (including fungi) cultivation and animal breeding for food, fiber, biofuel, medicine, and other products for sale, own consumption, and industrial purposes. The class includes fallow land, agricultural land terracing, drainage network, green houses, and other building related to agricultural activity.
    - **Plant agriculture** refers to the practices of growing crops (including fungi); it is defined by three element types:
        - **Exploitation types**: It is defined by a type list which is explained below:
            - **Commercial farming** is a type of mechanized agriculture where crops are grown for commercial use only. It is an intensive

agriculture in one or more sectors. It generally includes an increased use of fertilizer, plant growth regulator and pesticides.

- **Partly commercial farming** is a type of mechanized agriculture where crops are grown both for individual and commercial use. They are intensive farms, usually smaller than those in the previous class and with more sustainable intensive cultivation methods.
- **Subsistence farming** 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 to some degree.

- **Intensity types**: defines the fraction of the cultivated area that is harvested. A detailed types of list will need to be developed and standardized or documented in a register.
- **Scale types**: defines the general character of the business unit known as a farm. Therefore, the major discriminant is the type of labour supply. It is defined by three types:
  - **Large scale**: any kind of farming where the managers do not do the manual work but mainly work in a supervisory role.
  - **Medium scale:** any kind of farming where the farmers do some part of the work but not entirely.
  - **Small scale:** any kind of farming (and members of the family) where farmers do all of the work.
- **Animal farming** is the practice of breeding animals to produce animal products or recreational purposes. A detailed types of list will need to be developed and standardized or documented in a register.

- **Inland water and marine food production** includes professional fishing and aquaculture in both inland waters and seas.
- **Inland water aquaculture and fishing** includes professional fishing and aquaculture in inland water areas.
- **Inland water aquaculture** is the farming of aquatic organisms including fish, mollusk, crustaceans, and plants in inland water (see Appendix-B for aquaculture types).
- **Inland water fishing** is professional fishing in inland waters. The fishing is mainly done in freshwater, rivers, lakes, inundated plains, swamps, and marshes, inundated paddy fields, etc. (see Appendix-B).
- **Marine aquaculture and fishing** include professional fishing and aquaculture in seas (Appendix-B).

- **Marine fishing** is the industry or occupation devoted to the catching and processing of fish, shellfish, or other aquatic animals. Marine fishing types are listed in Appendix-B.
- **Marine aquaculture** is the farming of aquatic organisms, including fish, molluscs, crustaceous and plants in the sea. Marine aquaculture types are listed in Appendix B.
- **Natural products gathering** is the collecting of natural products as non-wood-based products (mushrooms, berries, etc.). The class includes non-professional fishing and hunting.
- **Terrestrial product gathering** is the gathering of natural products in a terrestrial ecosystem.
- **Hunting** pursuit and killing of wild animals for food, sport, or profit. Hunting types are listed in Appendix-B.
- **Natural products picking** is the picking up of natural non-wood products.
- **Inland water and marine natural products harvesting** the collection of inland water and sea products, including non-professional fishing.
- **Inland water natural products harvesting** is the collection of inland water products, including unprofessional fishing.
- **Marine natural products harvesting** is the collection of sea products, including non-professional fishing.
- **Forestry** is the practice of planting and taking care of large areas of trees. A detailed types list will need to be developed and standardized or documented in a register.
- **Extraction** is the extraction of solid, liquid or gas minerals or materials by different methods as underground or surface mining and quarrying. It is defined by three element types:
  - **Position** is defined by two parameters which are as under:
    - **underground**: excavation of material under land surface, and
    - **surface**: category of mining in which soil and rock deposits overlaying the minerals are removed.
  - **Mining types** see types list provided in Appendix B.
  - **Extracted mineral types** see types list provided in Appendix B.

2. **Secondary production:** is industrial or manufacturing industries that use the material derived from direct production and transform them into finished goods or intermediate products for other trade. It is dominated by the specific industrial sector involved in the manufacture of finished products.

- **Raw end product**: industry includes the industrial activities that transform products of direct production into manufactured raw products. For instance, textile, chemical, manufacturing of metal, non-metal, rubber, wood, and paper products.
- **Heavy end product**: industry includes the industrial activities that transform products of direct production into manufactured heavy products. For instance, machinery and transport equipment.
- **Machinery production**: includes the industrial activities that transform products of direct production into different types of machinery. Machinery types listed in Appendix B.
- **Non-machinery production**: includes the industrial activities that transform products of direct production into vehicles and transport equipment. Non-machinery types are listed in Appendix B.
- **Light end product industry**: includes the industrial activities that transform products of direct production into manufactured light products. For instance, manufacturing of clothes, books and newspapers, electrical equipment furniture etc., Light end product industry types listed in Appendix B.
- **Energy production:** is the production and distribution of energy. Energy production types listed in Appendix B.

3. **Services and utilities:** is the delivery of services as products for other activities. It includes both public and private services. This class includes the utilization of infrastructures to provide basic utilities such as water and sewage treatment, distribution of electricity, gas, petrol, and pipelines for the transport of oil or gas.
    - **Services**: is the delivery of services as products for other activities, for instance, financial and insurance, information and communication, community, religious, health, and sport services, etc. The service types are listed in Appendix B.
    - **Utilities**: is the provision of basic utilities including the infrastructure devoted to their delivery and maintenance. The utility types are listed in Appendix B.
4. **Transport and logistic network:** is the delivery of services related to transport and logistics. Those services are delivered in specific infrastructures devoted to this network, such as airports, roads, pump stations, ports, docks and storage areas, and related infrastructures.
    - **Transport network**: is the delivery of services related to transport. Those services are delivered in specific areas and/or infrastructures devoted to it. The transport network types are listed in Appendix B.

- **Logistic network**: is the delivery of services related to logistics. Those services are delivered in specific areas and/or infrastructures devoted to it. The logistic network types are listed in Appendix B.

5. **Residential** is an area in which the main function is housing for people. Those areas can include a large variety of housing types as single or multi-family housing and mobile homes etc. The residential types are listed in Appendix B.
6. **Conservation protection** is the act of conservation and protection of plants and animals and natural areas. (See Appendix B).
7. **Heritage** is the act of preservation of specific structures belonging to the culture of a particular society in the past or present. Heritage types listed in Appendix-B.
8. **Restricted** is the act of regulating and limiting access to specific controlled areas.
    - **Easement:** is a particular concern/limitation on an area owned by another that sanctions its holder to a specific use: Easement types are listed in Appendix B.
    - **Risk exposure:** is the application in specific areas or infrastructures of particular regulations related to the risk of any nature. Risk exposure types are listed in Appendix B.
    - **Restriction:** is the application in specific areas of an access restrictions. Restriction types are listed in Appendix B.
9. **Buffering and Shielding** is the purpose of specific areas or infrastructures to protect and defend against specific hazards, such as flooding, erosion etc.
    - **Buffering:** buffering types listed in Appendix B.
    - **Shielding:** shielding types listed in Appendix B.
10. **Insubstantial** is defined as a weak or undefined function:
    - **Not under distinct use:** is an area where the use is vague, undistinguishable, or indefinite.
    - **Other**: any other function not listed.

Appendix B: Function types

This is a tentative draft list that will be further refined and improved with other existing function types as for instance Standard Industrial Classification (SIC).

Inland fishing types (to be defined according to UN or other national and international organization list). Inland aquaculture types are as follows:

- **Fish farming:** raising fish commercially in tanks or fishponds, usually for food.
- **Shrimp farming:** raising shrimps in fresh water for food production.
- **Ornamental fish farming:** raising of fish species suitable for aquariums.

Marine fishing types (to be defined according to U.N. or other national and international organization list). Marine aquaculture types are as follows:

- **Fish farming**: raising of fish in the open ocean.
- **Shrimp farming:** raising of shrimps in marine water for food production.
- **Oyster farming:** raising of oyster for food production.
- **Algae culture:** farming of different species of algae mainly micro-algae.

Mining types are as follows:

- **Strip mining:** removal of soil and rock above a layer or seam, followed by the removal of the exposed mineral.
- **Seabed and sand river mining:** extraction of submerged minerals and deposits from the sea and river.
- **Shaft mining:** excavation of a vertical or near vertical tunnel from the surface down into the ground to where there is initially no access to the bottom.
- **Drift mining:** a mining technique where the opening is dug directly into an outcrop of minerals (e.g. coal or ore).
- **Room and pillar mining:** an extraction system on which the mineral is extracted across a horizontal plane.
- **Slope mining:** an extraction method where the access to the material is on an incline.
- **Block caving:** a method of extraction of large blocks of ore by systematically undercutting so the ore will cave.
- **Quarrying:** a method of excavation of pit, usually open to the air, from which building stones, slate, or others are obtained by cutting, blasting, etc.

- **Open pit mining:** an open pit where the minerals are near the surface.
- **Hydro mining:** a form of mining that uses high pressure water to dislodge rock materials or move sediments.

Extracted mineral types are as follows:

- Iron
- Coal
- Uranium
- Phosphate
- Copper
- Limestone
- Bauxite
- Gold
- and others

Raw end industry types are as follows:

- **Wood and wood-based products** includes facilities where trees are transformed in wood products.
- **Textile products:** an industry that is primarily concerned with the design, processing and production of yarn, cloth and clothing.
- **Paper and pulp paper products:** industries that use wood as a raw product and manufactures pulp, paper, and other cellulose-based products.
- **Refined petroleum:** an industrial process where crude oil is transformed into different types of products such as petrol, naphtha, gasoline, diesel fuel, asphalt base, kerosene etc.
- **Chemical products:** companies that produce different types of chemicals.
- **Man-made fibers:** industries that produce fibers from both natural and synthetic polymers.
- **Basic and fabricate metals:** industries devoted to the manufacturing processing and casting of different types of metals (iron, steel, etc.).
- **Non-metallic products:** industries devoted to the manufacturing of glass, bricks, ceramics, plasters, etc.
- **Plastic and rubber products:** manufacturing of polymer materials and/or rubber.
- and others.

Heavy end industry types are as follows:

- **Agricultural and other machinery:** manufacture of agricultural, forestry and other types of heavy machinery including domestic appliances (excluding vehicles and aircraft).
- **Weapon machinery:** manufacture of weapons and ammunitions.
- **Vehicles and heavy transport machinery:** manufacture of cars, trucks, other vehicles, air and space crafts, boats, railways, and tramways equipment, etc.
- and others.

Light end industry types are as follows:

- **Food and beverages:** production and distribution of edible goods.
- **Tobacco:** production of derived tobacco products.
- **Clothes:** manufacture of clothes, dressing accessories etc.
- **Publishing and printing:** manufacture and printing of newspapers, books, sound recordings etc.
- **Electrical equipment:** manufacture of any type of electrical equipment (computers, phones, TVs etc.).
- **Optical equipment:** manufacture of any type of optical instruments.
- and others.

Energy production types are as follows:

- **Nuclear:** production of power through a nuclear reactor.
- **Hydroelectric:** production of electricity made by generators pushed by movement of water.
- **Fossil fuel-based energy production:** production of electricity made by power stations that use fossil-based materials as fuel.
- **Biomass based energy production:** production of energy made by stations powered by biomass-generated gas.
- **Solar, wind and other renewable energy production:** production of electricity made by solar, wind and other renewable resources.
- Others

Service types are as follows:

- **Automobile sales and repair or services establishment:** selling of motor vehicle and part dealers (including selling of medium and heavy trucks).

- **Real estate services:** provision of real estate for ownership, leasing, and renting.
- **Furniture or home services:** retail furnishing establishments that sell products such as household, outdoor and office furniture, etc.
- **Hardware and home service centers:** retail and selling of hardware, tools, and services.
- **Heating and plumbing:** services for heating and plumbing.
- **Other heavy consumer goods:** retail and selling of any other heavy consumer goods.
- **Accommodation services:** provision of services for hotels, camping sites, etc.
- **Food services:** provision of services for restaurants, bars, diners, cafeterias, etc.
- **Optical and computer services:** provision of services for computers cameras and other optical instruments.
- **Other consumer goods and services**
- **Health and personal care:** services for human and animal health.
- **Finance and insurance:** services for banking, credit other finance and insurance.
- R**ental and leasing of machinery and vehicles**
- **Professional, scientific, and technical services:** provision of services related to professional, scientific, or technical activities.
- **Administrative services:** provision of services related to any administrative activity.
- **Travel and tourist services:** provision of services related to travel and tourism (travel agency, guides, etc.).
- **Investigation and security services:** provision of services related to personal security and investigative activities.
- **Personal services:** provision of services related to all the aspects of human care (laundry, hair care etc.).
- **Pet and animal services:** provision of services related to pet and other animals (excluding for farming purposes) as pet supplies, dog training etc. (veterinary services are not included).
- **Community services:** provision of religious, defense, social, political, cultural, and recreational services.
- and others.

Utility types are as follows:

- **Sport** areas devoted to the provision of sports infrastructures such as stadiums, swimming pools, golf courses, tracks, etc.
- **Recreational** areas devoted to the provision of recreational activities such as urban parks, playgrounds, and natural areas.
- **Water and sewage treatment** areas devoted to the provision of water and sewage treatment including collection, extraction, and purification.
- **Pipelines for oil or gas** areas devoted to the transport of oil or gas.
- **Waste treatment** areas devoted to the different types of treatment and management of waste.
- **Electricity distribution services** areas and infrastructures devoted to the distribution of electricity.
- **Gas and thermal power distribution services** areas and infrastructures devoted to the storage and distribution of gas and thermal power.
- and others.

Transport network types are as follows:

- **Road:** roads and related infrastructures.
- **Railway:** railways and related infrastructures.
- **Port and related infrastructures:** ports, docks, and any other related infrastructure.
- and others.

Logistic network types are as follows:

- **Logistic infrastructures services** any type of infrastructure used for logistic service.
- **Storage services** any utility and infrastructure used for storage of goods.
- and others.

Residential types are as follows:

- **Private household:** all households except the ones used for special provisions and services (retirement housing services, hotels, etc.)
- **Housing services:** housing services for personal care, custodial etc. (retirement housing, life care, congregate living, etc.)
- **Hotels, motels, and other accommodation services:** services for lodging and short-term accommodation.

- and others.

Conservation or protection area types are as follows:

- **Strict natural reserve and wilderness area:** protection of large unmodified, or slightly modified area retaining their natural character and influence, without permanent or significant human habitation which are protected and can serve as reference for scientific research and monitoring ((International Union for Conservation of Nature -IUCN) (Dudley, N. 2008 and 2013)).
- **National park:** protection of large natural or near natural areas set aside to protect large scale ecological processes (IUCN definition).
- **Natural monument or features:** protection of specific areas (generally small) containing distinct natural monuments (landform, sea mount, subterranean cavern, any other geological feature formed through natural forces).
- **Habitat management areas:** protection and conservation of areas that are habitats of species, often designated flora and fauna in terms of viability or fragility.
- **Protected landscape or seascape:** protection and conservation of areas of peculiar distinct character due to the interaction of people and nature over time.
- and others.

Heritage types are as follows:

- **Historic:** normative rules for particular places of significance on account of historical values.
- **Cultural:** normative rules for particular places of significance on account of cultural values.
- **Indigenous:** normative rules for particular places of significance to people that are native to an area or who naturally belong to it by virtue of longevity or treaty agreements.
- and others.

Easement types are as follows:

- **Public:** easement (designated or restricted access) of a public area
- **Airport:** easement of airport infrastructure
- **Railroad:** easement of roads and related areas
- **Beach:** easement of beaches and related infrastructures
- **Energy production:** easement of energy production infrastructures.

- **Pipeline:** easement of pipelines surrounding areas.
- and others.

Hazard exposure types are as under:

- Flood
- Chemical contamination
- Nuclear contamination
- Mining
- Erosion
- and others

Restriction types are as follows:

- Military
- Industry
- Public
- and others

Buffering types are as follows:

- Inland water
- Marine water
- and others

Shielding types are as follows:

- Inland water
- Marine water
- Winds
- Erosion
- and others

Appendix C: Examples of land use classification systems

Some examples of the most recent LU classification systems are:

Australian land use and management system

In 1999, a joint workshop involving national, state and territory authorities agreed to a national land use classification for Australia (ALUM, 2016), based on a modified version of the scheme developed by Baxter and Russell (1994). The aim was to promote the creation of nationally consistent land use datasets to meet a wide range of user needs and make the best use of existing data and available resources.

The Australian land use and management (ALUM) classification has since been revised in July 2000 (version 3), October 2000 (version 4), February 2002 (version 5), June 2005 (version 6) and May 2010 (version 7) through consultative review processes. The most recent revision of ALUM classification is dated October 2016 (ALUM v8).

Structure of the system

The ALUM classification has a three-tiered hierarchical structure. Primary, secondary, and tertiary classes are broadly structured by the potential degree of modification and the impact on a putative natural state (essentially, a native LC).

Primary and secondary classes relate to land use - the main use of the land, defined by the management objectives of the land manager. Tertiary classes can include commodity groups, specific commodities, land management practices or vegetation information.

The ALUM classification includes six primary classes. The five primary classes of land use are distinguished in order of increasing levels of intervention or potential impact on the natural landscape. Water is also included as a sixth primary class.

Land based classification standards system

In 1996 the American Planning Association (APA) initiated the update of the Standard Land Use Classification (SLUC) dated 1965. The result of this update lead to the generation of a new approach to classify LU from a planning perspective the land based classification standards (LBCS). The LBCS distinctive approach is that it refers to specific land-based information to provide planners with a consistent model for classifying land uses based on their multidimensional aspects. Land based information includes all types of land uses and LU activities including those aspects of LC and land rights information used in planning applications.

LCBS is based on a multi-dimension aspect to define a LU category, those aspects are as follows:

1. Activity, actual use of the land
2. Function, economic function of the land
3. Structure, type of structure or building of the land
4. Site, overall physical development of the land

The INSPIRE land use specifications

The data specification on LU was developed in 2012 by the INSPIRE Thematic Working Group (TWG) on LU. The system is done in both natural and conceptual schema languages. Basically, the system is mainly used by experts using UML diagrams in order to offer a rapid way to see the main elements of the system and their relationships. However, users not familiar with UML schemas can understand the model by focusing on the Feature Catalogue.

The model follows the EU INSPIRE on which land use is characterized according to the current and future (planned) functional dimensions (or socio-economic purpose) of a piece of land. The system is split into 6 main Functional Dimensions:

- Primary production
- Secondary production
- Tertiary production
- Transportation network, logistic and utilities
- Residential use
- Other use

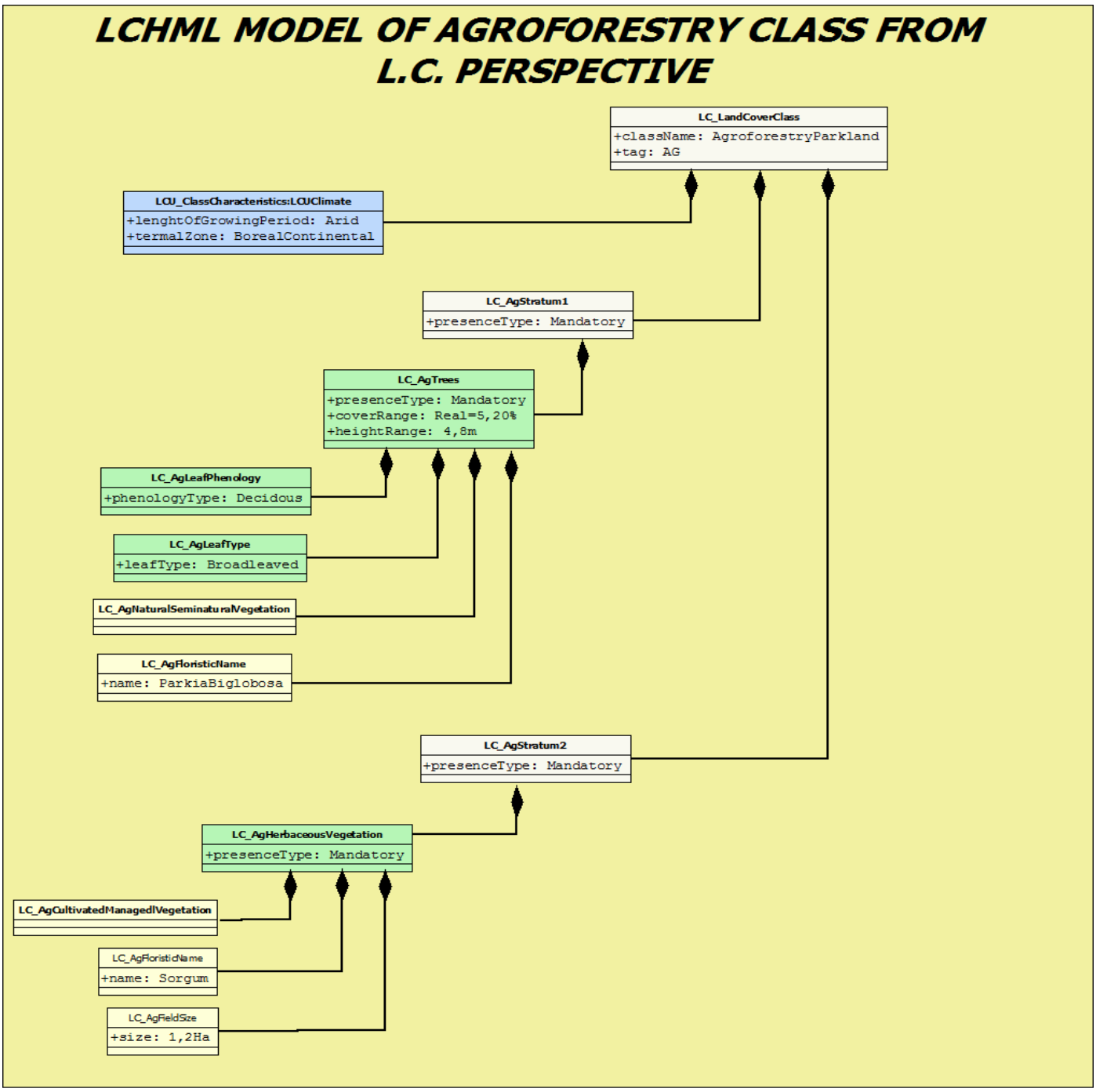
Appendix D: Descriptive examples

The Appendix presents a number of descriptive examples of LCHML to define a specific land situation. The base example considers a typical agroforestry system in Sub-Saharan Africa called parkland agroforestry (Figure 15). It is broadly defined as an area where scattered multipurpose trees occur in farmlands as a result of farmer selection and protection. These parklands include long-term cultivation.

Figure A.D.15: A typical parkland agroforestry area in sub-Saharan Africa

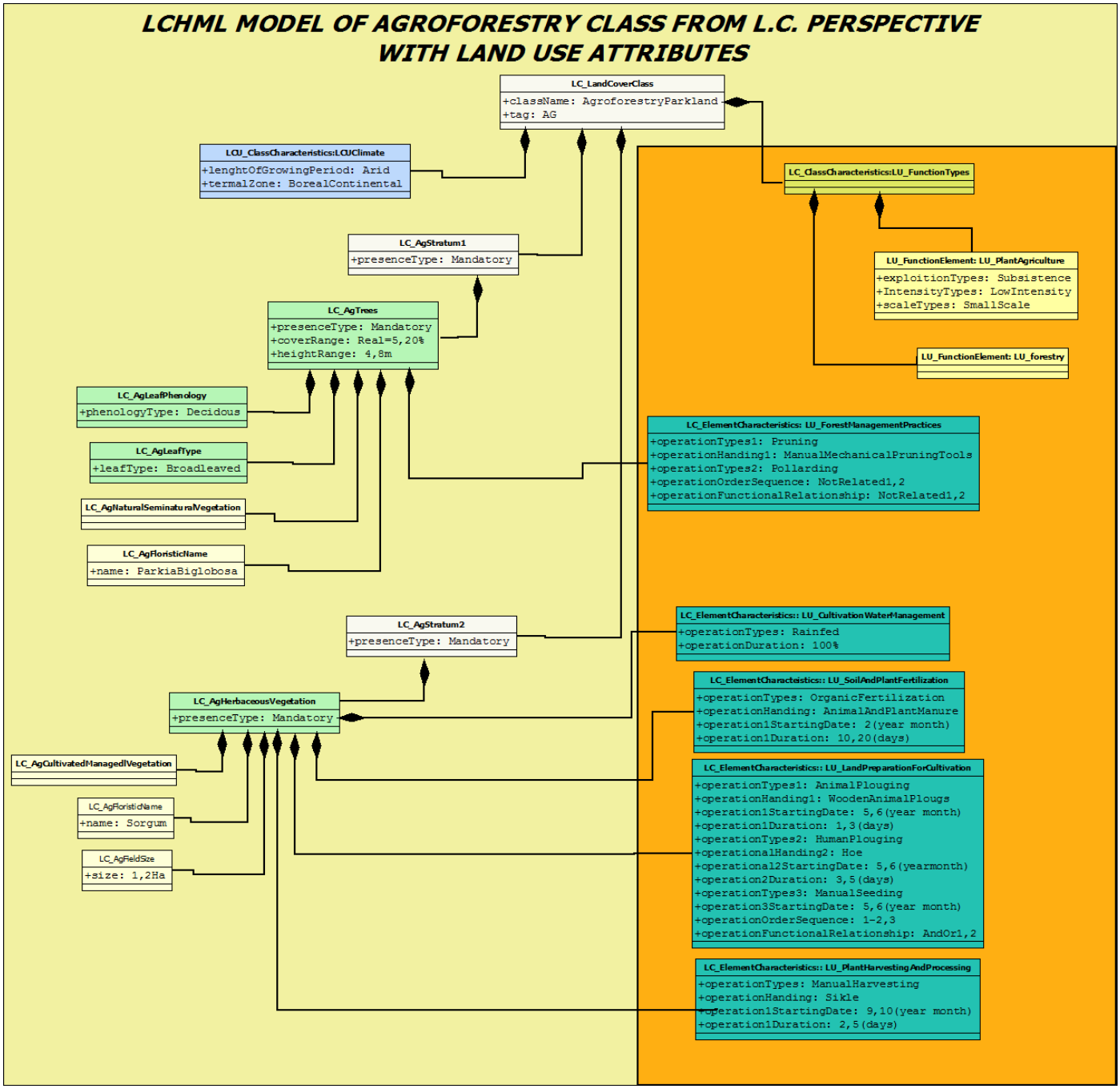
Example 1: Presents a pure LC description of a parkland agroforestry system. The model can be used to describe the sole physiognomic/structural aspect of the area (Figure 16). Two major elements are considered: trees and herbs. The information about these two elements, organized in different layers, are then enriched with a series of different types of attributes (defined in the model as proprieties 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 end the trees are defined as broadleaf deciduous, scattered (cover 5-20%), floristic type park a biglobosa. Basically, this is the kind of information that can be derived from a satellite image and is reported in a normal LC legend.

Figure 16: Model representation of the area from the strictly the LC point-of-view



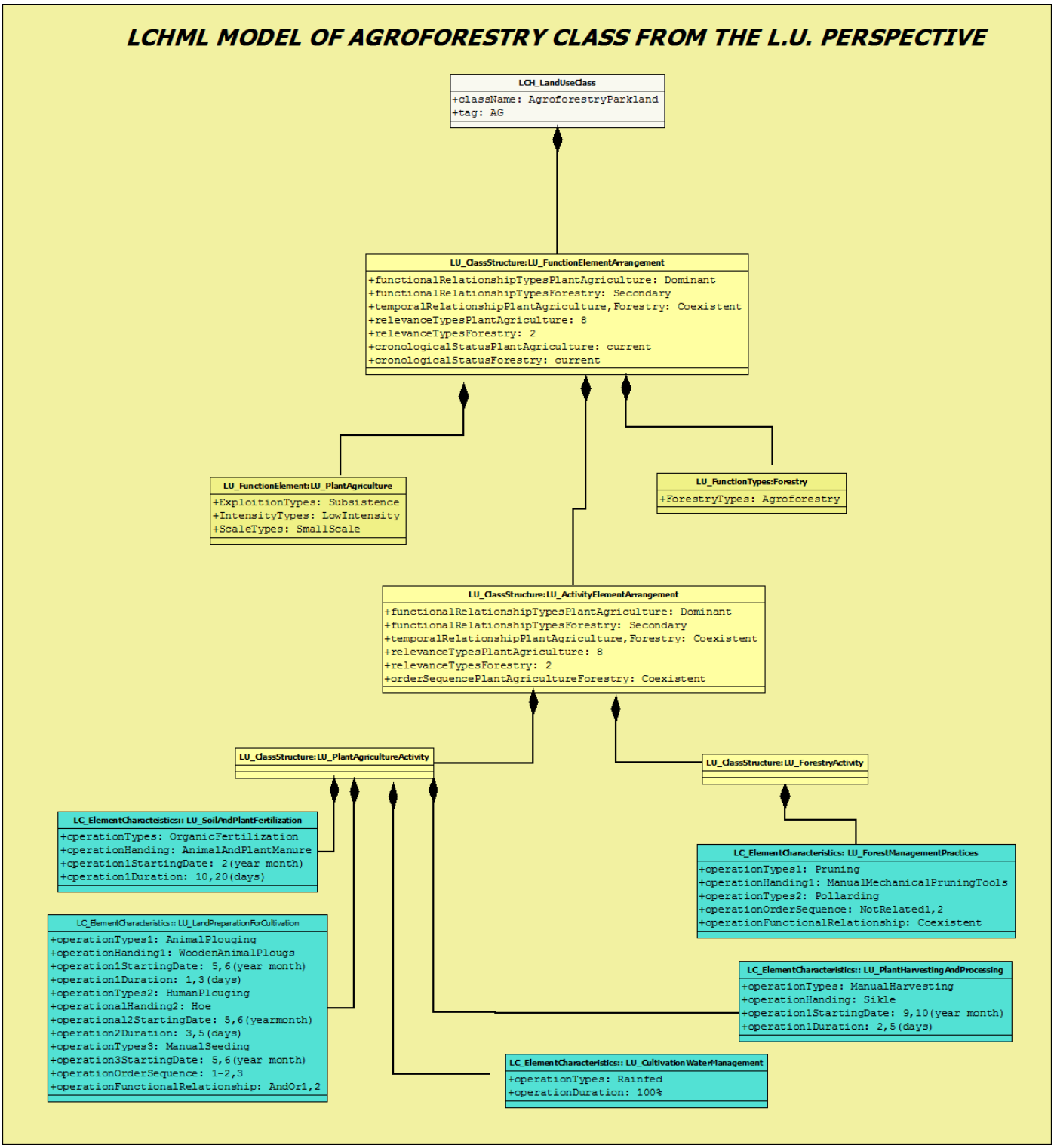
Example 2: Presents a LC description of a parkland agroforestry system with additional LU information (Figure 17). In this case, the model allows the user to further improve the basic LC information with a description of the LU purpose (LU Function) of the land and the activities people are doing on it. In this case the model still has its central structure, the LC component, but this main component is further enriched with specific LU attributes. In the example the LU functions are simply attached as attributed to the final class, while the LU activities are linked to the main physiognomic objects of the class (Trees and Herbs).

Figure 17: Model representation of the area from the LC point-of-view enriched with extra LU attributes (brown box)



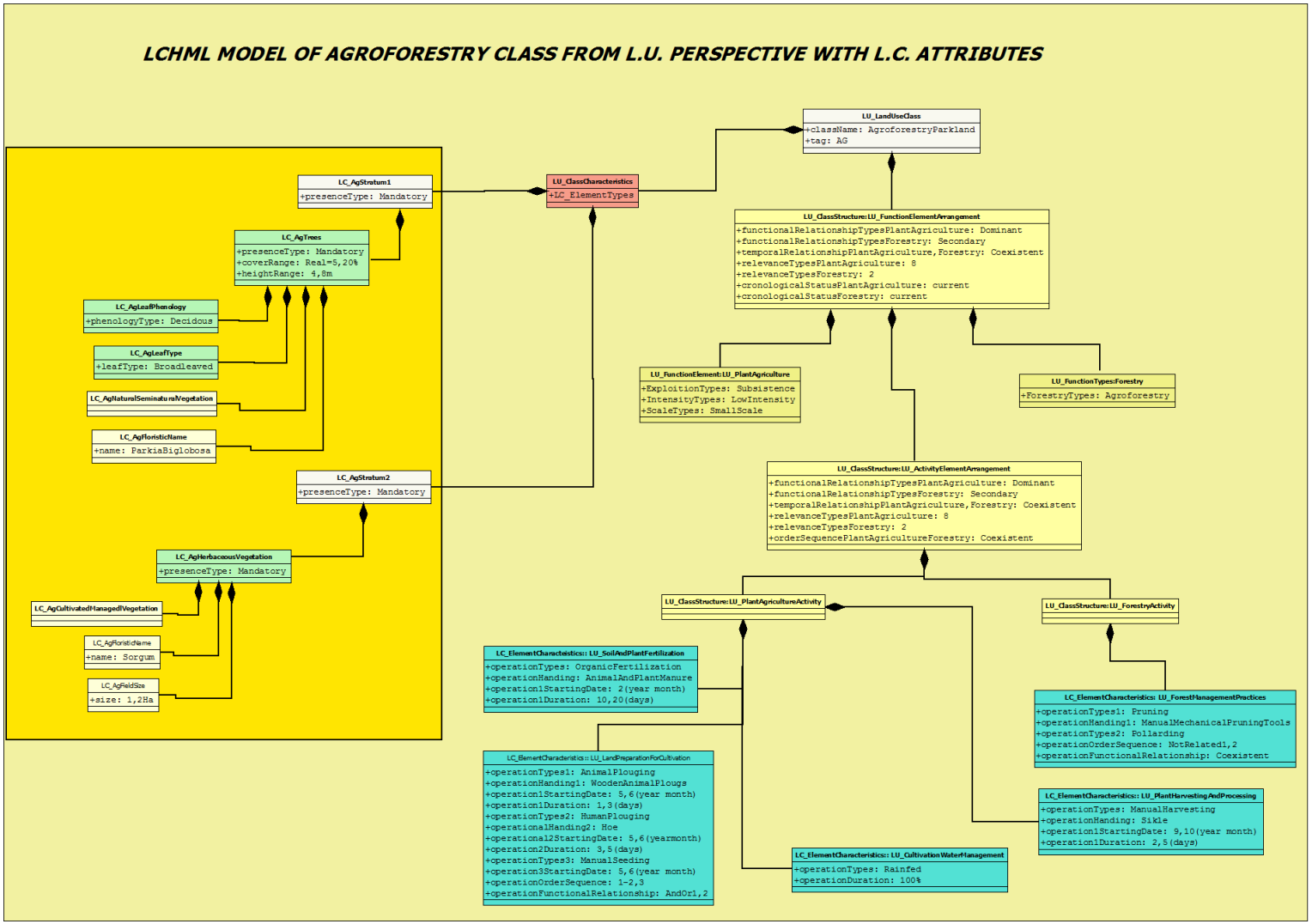
Example 3. Presents a LU description of a parkland agroforestry system (Figure 18). The model can be used to describe the area purely from the LU point of view, that means the description of the main purposes (LU Functions) that characterize this specific land and the different activities people are undertaking on it. Both functions and activities are further characterized within and between themselves with specific types of relationships.

Figure 18: Model representation of the area from a purely LU point-of-view



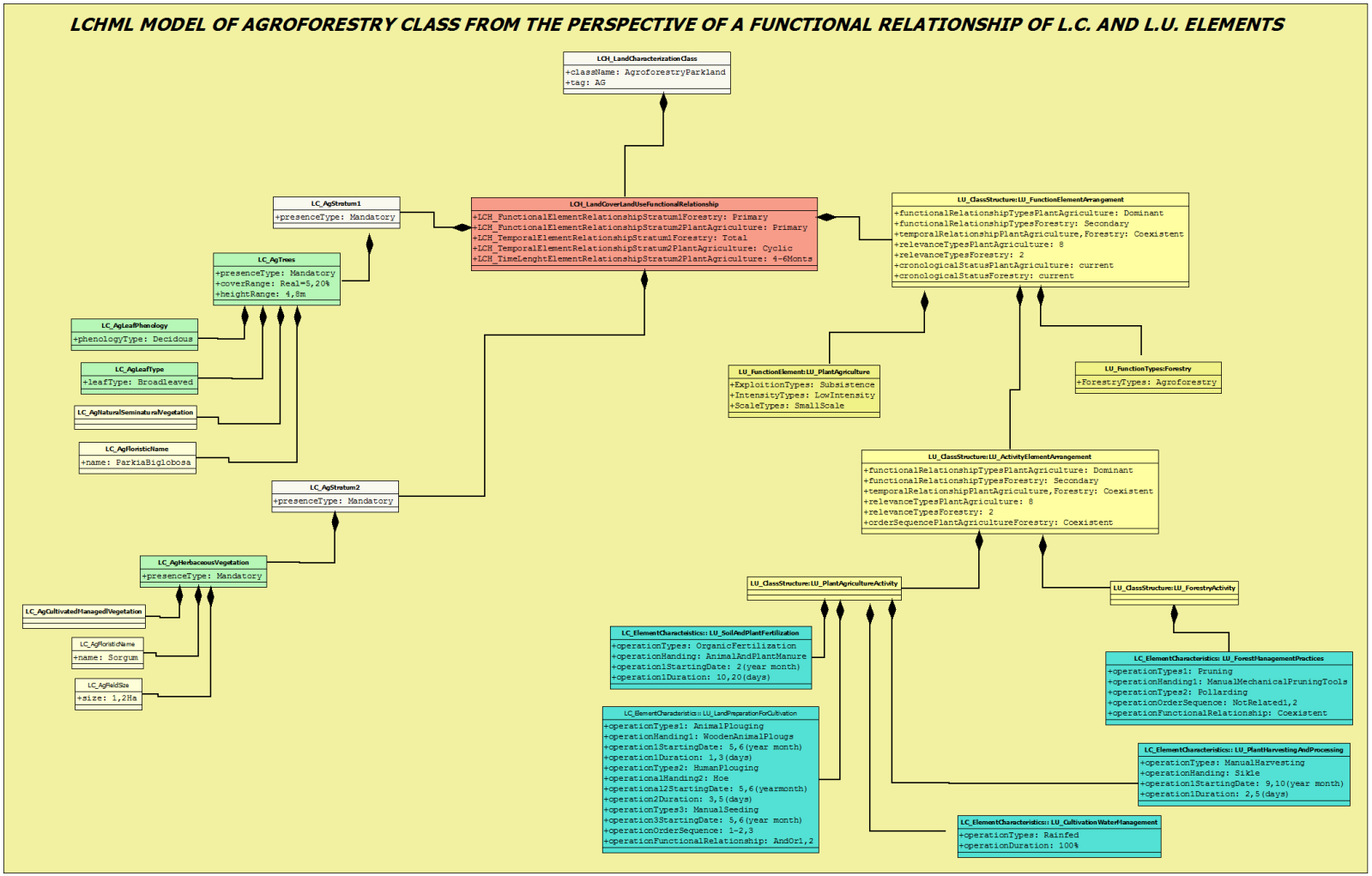
Example 4: Presents a LU description of a parkland agroforestry area with additional information on basic LC attributes (Figure 19). In this case the model allows the user to further improve the LU description that is the main component of the model, with further information on the physiognomic/structural aspect of the natural objects (trees and herbs) present in the area. This LC information is attached to the LU class through a specific LC attributed element.

Figure 19: D4 Model representation of the area from a LU point-of-view enriched by LC attributes (yellow box)



Example 5 is the most comprehensive representation of the parkland agroforestry area the model can outline. In this case LC and LU information are the main components of the model (Figure 20). Basically, the user can give a full description of the area using the physiognomic structural description of the basic objects (LC description) and the purposes (functions) for which the land is used together with the activities people are undertaking on it (LU description). All these different LC and LU elements are linked through specific model procedures that assure their fully efficient and functional relationship. This ensures the capability to describe a specific aspect of the land while also endeavoring to model the complex and intricate relationship among the different elements.

Figure 20: Model representation of the area linking together LC and LU information



The land characterization meta-language

A new approach to define the primary aspects of the land through the functional relationship of its biophysical and socioeconomic characteristics

There is a clear relationship between Land Cover and Land Use (LCLU). In fact, many existing land use classifications are based on land cover information and vice versa. In practice, in many instances LCLU concepts are so closely interrelated that often the meaning of terms becomes interchangeable. The description of a portion of land includes both LCLU information (described as the biophysical land components and the human activities that shape and/or modify them). In a modern and efficient system, one cannot substitute one for the other. However, the two are and must be well separated concepts. Therefore, an effective and functional relationship between LCLU needs to be established formally.

This publication attempts to show this relationship. The title, and characterization meta-language, is used in this paper to represent the combination of the description of the terms LCLU. The land characterization meta-language includes both LCLU and the bridging relationships between them. The land characterization meta-language schema follows the premise that an effective and functional LCLU relationship can be built only with a change of paradigm creating a unified modelling language schema based on the three-way relationship between the biophysical cover, the activities being performed and the functions to which the land is devoted at a point in time.

ISBN 978-92-5-138637-8

9 789251 386378

CD0064EN/1/04.24