A CROPLAND NOMENCLATURE

conform to the FAO LCML

(LAND COVER META – LANGUAGE)

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Introduction

The classification of agriculture and/or agriculture systems has a long history of production of different methods and approaches and most probably will continue to generate a large variety of different systems in the future. In reality does not exist any common classification that is widely accepted and that can adequately serve the multiplicity of goals and purposes for which a reference system should be asked for. The reasons for this limitation are many, but two can be pointed out as decisive:

- The inherent constraint of any categorization process
- The variety of perspectives from which to observe and define agriculture and/or agriculture systems

The first aspect will be deeply discussed in the next chapter; the second problem derives from the land use origin of agriculture itself as a "prominent activity of humans in a certain piece of land". This human modification of the natural landscape for agricultural purposes it is so heterogeneous that can be as diverse as any part of land surface under human intervention itself. Therefore the different perspectives from which an agriculture system can be identified/perceived leads to a large variety of criteria to built up a classification system. Cultivation classifications may be based on the following:

- According to crop type or crop commercial value
- According to the crop rotation type or intensity of rotation(shifting cultivation system, fallow system, perennial crops system, lay system etc)
- according to water supply (irrigated versus rain fed)
- according to the agricultural land availability (extensive versus intensive farming)
- according to cropping patterns
- according to the degree of commercialization (subsistence versus commercialized farming)
- according to the ownership of the area of the farming land (estate, cooperative or collective farming systems)

The introduction of satellite remote sensing for the detection and monitoring of agriculture classes has introduced an extra higher level of multiplicity on the definition and classification of agriculture.
Remote sensing has long been used in monitoring and analyzing agricultural activities. Well prior to the launch of the first satellite apparatus scientists were using aerial photography to complete soil and crop surveys associated with agricultural areas. For instance since the 1930 the U.S. Department of Agriculture started general crop inventories and soils survey mapping using aerial photographs as part of the work of the then U.S. Soil Conservation Service.
In the early 1970s, when the first satellites became operational many agriculture inventories have included many types of sensors, and remote sensing has been proven capable of providing a certain type of information on a timely basis for a fraction of the cost of traditional methods of data gathering.

The spatial nature (always referring to a specific localized geographic extend) and the inherent characteristics and nature (including their limitations) of these data has lead to a large variety of classifications/local legends/nomenclatures that combines both Land Cover and Land Use terms. Far from systematic and comprehensive of many important cultivation practices/aspects, these systems tend to define a sort of "parallel reality" (the one that can be" effortlessly" observed by remote sensing) neglecting or marginalizing other aspects that needs more composite efforts. Often this existent limitation of remote sensing data sets is covered out by a variety of terms and definitions built up with a high degree of semantic vagueness and ambiguity. The common practice to use "single ontology" systems (the semantic meaning and standardization capability of a certain category is limited to its name and ,when present, text description) enlarge the dissonance of terms that even when sharing the same title can have different meaning if utilized in data derived from remote sensing or from other sources (traditional statistic for instance). One of the objective of this exercise (see chapter 3) is to offer a solid conceptual framework to try to relate the large variety of terms used in remote sensing studies with the others(at least the ones used in traditional agricultural statistics). In other chapters of the report the general objectives and the overall structure of the system will be deeply analyzed, in this section it is important to clearly delimit the definite boundaries on which this proposed system will work. The name of the system "Cropland Nomenclature" try to define the broad scope of the exercise were:

- Cropland: is defined as "Land used for cultivation of crops", this implies the schema will try to define/order any piece of land were a certain type of crop is cultivated. The system will not consider the different practices of animal rising as included in the more general term "Agriculture". Grazed areas as well as "Pastures" are also excluded, however "pasture" areas were a minimum of human intervention is usually done as the mowing of the natural grass in "Meadows" areas are associated to the system trough an external connection(see next chapters). The present schema do not deals with broader categories as "Farming System" or similar that normally refer to a more complex arrangement of farming enterprises managed according to well defined practices in response to physical, biological and socio economic factors. However the categories present in this schema can contribute to a more strict definition of the physical characteristics present in the mosaics of cultivation aspects of a farming enterprise.

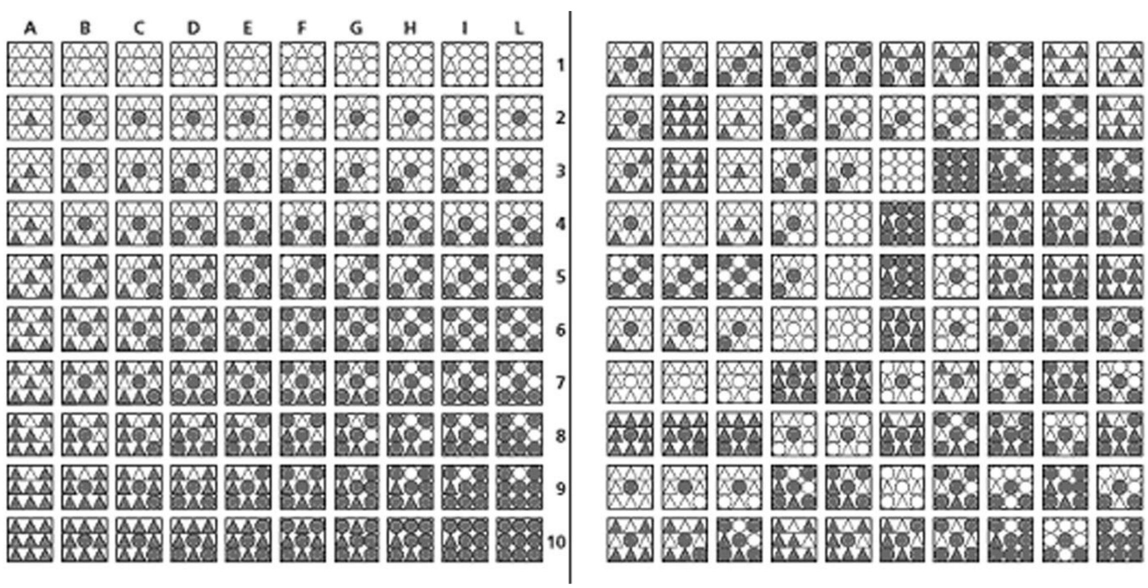
- Nomenclature: is defined as "a System or set of terms used especially in a particular discipline". In effect in the present system the emphasis is on the rules governing the definition of a class rather than on the class names. Therefore the present schema should be considered as "a defined and unambiguous set of rules and conditions to define certain features ". Each of the main features of the system should represent main general cropland aspects and can be further detailed with a large series of distinct attributes.

Chapter 1 Aspects and Issues of Semantic Interoperability

1.1 Classification and legends

The necessity to categorize different aspects or activities of the real world is an old and common practice. We live in a normalized world; our lives are surrounded with systems of classification, limned by standards, formats, etc. Therefore classify is not an occasional human activity but a common practice in the human life that we experiment several time in a day. The oldest method to communicate knowledge is, no doubt, human language and conversation, where specific language elements or specialized terms are created to exchange particular types of information. A body of shared knowledge as a basis for communication is therefore part of most sciences, and historically we find ample evidence of specialized terminology, hierarchical thinking and classifications established within those disciplines. Each discipline has its own vocabulary.

In the case of spatial information, classification is an abstract representation of features of the real world using classes or terms derived through a mental process.
Sokal (1974) defines it as: “the ordering or arrangement of objects into groups or sets on the basis of their relationships”, and Bowker and Star (1999) as: “a spatial temporal or spatio-temporal segmentation of the world”. They define a ‘classification system’ as “a set of boxes (metaphorical or literal) into which things can be put in order to then do



some kind of work bureaucratic or knowledge production”.

The figure 1 (above) shows an abstract representation of a classification consisting of a continuum with two gradients (left), in comparison with a concrete field situation (right). Triangle and circles represent the two elements being considered. Source: From Kuechler and Zonneveld, 1988.

A classification, therefore, describes a systematic framework, with the names of the classes, the criteria used to distinguish them and the relationship between classes

themselves. Classification thus requires the definition of class boundaries, which should be clear, precise, and possibly quantitative and based upon objective criteria.
In an abstract, ideal sense a classification system should exhibit the following properties:

- Use of consistent, unique and systematically applied classificatory principles.
- Adapted to fully describe the whole gamut of features types.
- The system is complete, providing total coverage of the world it describes.
- The classes derived from it are all unique, mutually exclusive and unambiguous.

Classification endeavours to address an entire information domain and subdivide it according to a set of rules to produce a set of classes and sub-classes allowing for all of the possibilities in the logical space. In an a posteriori classification system a number of classes have been selected from the entire logical space.

1.2 **Harmonization versus standardization**

Harmonization should be the process whereby similarities between existing definitions of land characterization are highlited/explained and inconsistencies reduced. However this is not the actual case were current systems exist prevalently as independent and incompatiable data sets.
The ultimate goal is to bring various systems in ‘harmony’, thus allowing direct comparison between them. This process follows a “bottom up” perspective. Beginning from a state of divergence in datasets it seeks compatibility and comparability. Harmonization does not necessarily eliminate all differences, but should eliminate major inconsistencies. Standardization, in contrast, is a “top down” process, and is therefore far more rigid. It requires common definitions and standards to derive geographic information and should eliminate all inconsistencies - and differences - between the different classifications. Harmonization essentially deals with existing definitions and attempts to harmonize the parameters used for description of a specific class and their definitions. Then, if these are applied or adopted it is possible to harmonize the individual criteria used to create categories of whatever name in whatever language. Ideally, harmonization should be guided by existing or evolving standards. Standardization assumes that all requirements (standards) are present during the development phase of a mapping or survey project. Given the multitude of users it is obvious that too much standardization reduces application, relevance and versatility of derived products and thus the approach that FAO has developed and successfully tested in the land cover domain is to standardize terminology rather than categories (FAO/UNEP, 1994). Basically, this is same approach adopted by soil science since the 1960s.

1.3 Shortcomings and problems of semantic interoperability with current systems

Categorization has always been a useful method to minimize the complexity of the real world and it is familiar to many aspects of our life. The process of categorization, however, is by far not a perfect approach in a modern management of information. Its limitations are partly inherent with its intrinsic nature of grouping the real world phenomena in a certain number of artificial categories. Reality is by its nature a “continuum”, and any partition of this virtual continuum into categories is intrinsically arbitrary and often reflects specific needs on the part of the data producer, and not necessarily reflecting the varied needs of individual end users. Threshold parameters, for instance, produce arbitrary and artificial differences in values in the real world (see fig. 2)

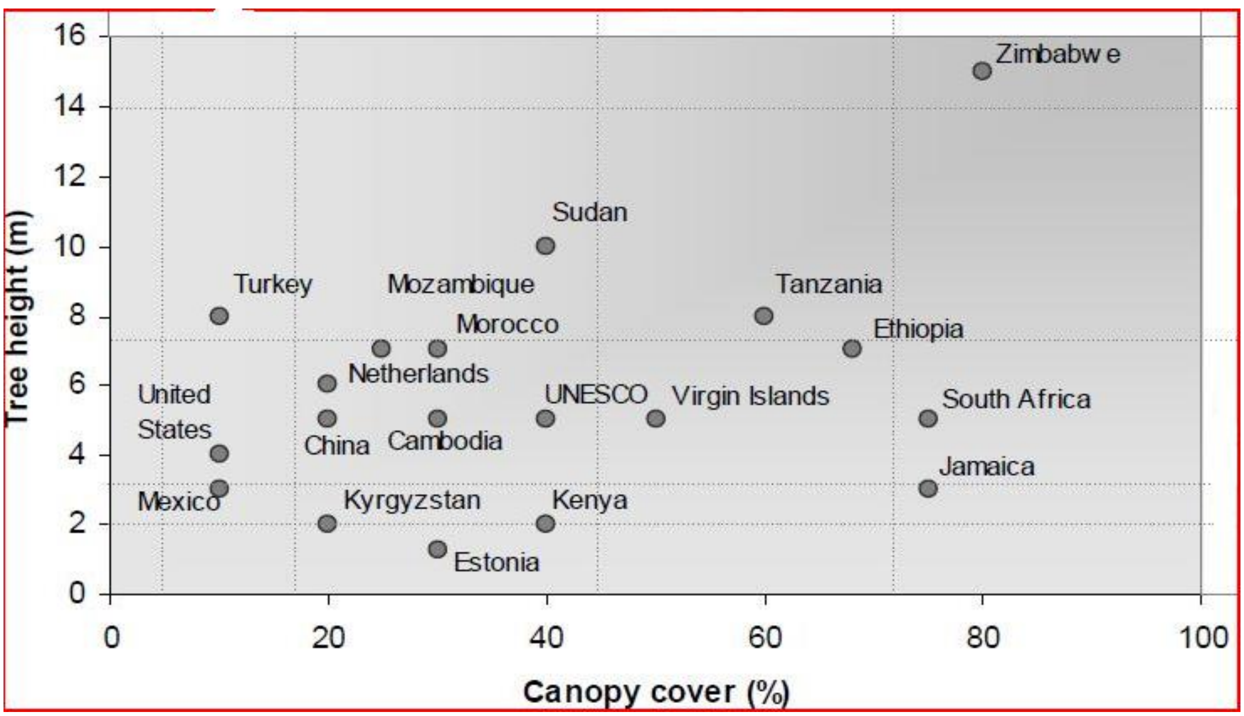


Fig 2 shows different thresholds parameters used in the forest definition that use land cover as core information.

Generalization, as well as the creation of the class itself, is often an arbitrary process In addition very little effort is generally put to the “formalization of the meaning” of each class. Formalization of the meaning is the way how the author of a classification system (legend) make official and manifest the ontology (intend as “meaning “or “significance” of the things) of the categories and explain their relationship. Unfortunately the persistent use of a “single ontology” systems (a class name with class description) with a predefined list of categories exacerbate the inherent problems of any categorization process (as described in the previous paragraph) introducing supplementary constraints that increase the fuzziness of the data and create huge interoperability problems.

Class definitions are imprecise, ambiguous or, very often, absent. The buildup of the definition in the form of a narrative text is unsystematic (many diagnostic criteria forming the system are not always applied in a consistent way) and in any case do not always reflect the full extent of the information.

Generalization into categories where meaning is very often limited to the class name, or has only an unclear class description, implies rigidity in the transfer of information from the data producer to the end user community. End users have limited if any possibility to interact with the data, and must therefore accept them ‘as is’. The representation of the granularity of the aspects summarizing a specific feature of the real world is drastically reduced or lost. Often some vagueness in the class definition is artificially included by the map producer to hide some ‘technical anomalies’ when reproducing a certain feature on the map. Moreover, vagueness or extreme complexity in the class definition makes it difficult to correctly assess the accuracy of the data set.

Structure of a data with just a name and a corresponding separate text description make it very difficult to manage the data set with modern GIS techniques.

In addition, usually, Categories (classes) are generally limited in number. This forces the data producer to drastically generalize the reality. Such generalization does not necessarily correspond to the needs of many studies, which ask for more and more detailed natural resources information. On the other end an opposite behavior would have as resultant effect an explosion in the number of classes, that can be unsystematic (an expansion of classes limited to only particular aspects of the real world due to the specific needs of a particular project) and therefore difficult to manage in a GIS system.

Semantic interoperability is actually the main challenge in Spatial Data Infrastructures (SDIs). Interoperability is defined as “the ability of systems to operate in conjunction on the exchange or re-use of available resources according to the intended use of their providers” (Kavouras and Kokla, 2002). In the case of ‘semantic interoperability’, we refer to the understanding of the ‘meanings’ of different classes and relations among concepts.

On these aspects, current classification and legends shows severe limitations that risk affecting the practical use of geographic information. The list below shows the most common problems encountered when dealing with semantic interoperability of classification systems.

- Different terms used for concepts (Synonymy).

- Different understanding of homonymous concepts (Polysemy) (e.g. the various meanings of the term ‘forest’ for forestry environmental modelling).
- Different understandings of the relations among common concepts.
- Common instances across databases assigned to different concepts in different ontologies.
- Common instances allocated to a more general concept in one hierarchy than in other.
- Equivalent concepts formalized differently.
- Equivalent concepts explicated differently.

On the basis of what above emphasized it should be evident that the idea of a unique standardized classification (legend/nomenclature) formulated with the old classic approach (name and text description) is a wrong paradigm and it will never successfully work? It must be clear that:

- ***Mapping (or conceptual representation of a particular geographic feature) is a local activity, so at one level it can be understood why there is the tendency to establish unique classification systems to fit local conditions***
- ***Any land surface is at a certain level (or scale of observation) heterogeneous and the standards to represent and generalize those land characteristics are about as diverse as the land itself***
- ***In geographic information truth as a distinct, incontrovertible and correct fact cannot exist***
- ***A classification (legend/nomenclature) of geographic phenomena is inherently subject to indeterminacy and relativism mostly reflected in its ontology***
- ***It should be recognized that no classification system can reflect the social and/or the natural world fully accurately***
- ***Classification (categorization) is an highly dynamic process related to geographic areas, time and culture***
- ***There are and it will be always multiple ways to categorize (segment) the real world phenomena, all of them have the same legitimacy***
- ***In the process of classify (categorize) both standardization and harmonization efforts are needed. The effectiveness of a classification process depends at which level standardization and harmonization are used***

1.4 The process of categorization – final considerations

Despite the obvious constraints, categories are useful means whereby we cope with the “continuous” nature of the real world and its multiplicity of information.

Categorization is also a powerful method how we share knowledge. Categories/specialized terminology are therefore part of most sciences, and historically we find ample evidence of specialized terminology, hierarchical thinking and classifications established within those disciplines. However the recent advances on many fields of information technology data management impose a modern and advanced approach to support evolving standards and in general the dynamic of science. In paragraph 1.1 the basic characteristic of an ideal classification system are listed, in addition to those conventional ones new properties are needed, therefore a modern system should :

- Be potentially able to converse with other systems. This inherent harmonization property should not relay (only) on expert judgment but the harmonization process should be automatized as much as possible.
- Recognize the balancing act inherent in classifying (Bowker and Star, 1999). A classification will never be able to fully represent all the aspects of the real world, therefore it must be clear it reflect (just) a specific scope for which has been developed.
- Render voice retrieval (Bowker and Star, 1999) by allowing users to detail and compare classes using a detailed class description (systematically organized with a list of explicit measurable diagnostic attributes), thus avoiding the risk of systems being impermeable to the end users.
- Standardization process should focus on the rules and conditions how a feature is conceptualized rather than acting just on the class name.
- The “formalization of the meaning” of the system and its components should be formulated with the most modern methods of modellization.
- A modern classification should not be considered an isolated structure but more a functional component of a rather complete system for data management.

Chapter 2 a new framework for classify geographic features

2.1 The FAO LCCS approach

In 1996, FAO made a contribution to upgrade the data categorization (mainly for Vegetation and Land Cover) by starting to develop a new approach. A new set of classification concepts were elaborated and were discussed and endorsed at the meeting of the International Africover Working Group on Classification and Legend (Senegal, July 1996) (Di Gregorio and Jansen, 1996, 1997a, b). The system was developed in collaboration with other international initiatives on classification of LC, such as the U.S. Federal Geographic Data Committee (FGCD) – Vegetation Subcommittee and Earth Cover Working Group (ECWG); the South African National Land Cover Database Project (Thompson, 1996); and the international Geosphere-

Biosphere Programme (IGBP) - Data and information System (DIS) Land Cover Working Group and Land Use Land Cover Change (LUCC) Core Project.

After a test period in the FAO Africover project in 1997–1999, the first official release of LCCS (v.1) was published in 2000 (Di Gregorio and Jansen, 2000). A second version was developed based on international feedback involving a large global community, and published in 2005 (LCCS v.2) (Di Gregorio, 2005). A new version (LCCS3) is planned for release in 2012.

LCCS adheres to the concept that it is deemed as 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 (classification system) (Ahlqvist, 2008).

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 (Ahlqvist, 2008).

During the practical use of the LCCS through the years, there has been an unexpected trend in the utilization of the system by the international user community. In addition to the creation of specific legends for specific applications, the system has also been used as a reference bridging system to compare classes belonging to other existing classifications.

In 2003, FAO submitted the LCCS to ISO Technical Committee 211 on Geographic Information as a contribution toward establishing an international standard for LC classification systems. This was the first time that this ISO committee had addressed a standard for a particular community of interest within the general field of geographical information. All of its previous standards had been higher level or abstract standards that established rules for application schema, spatial schema or similar concepts. There was some initial difficulty in initiating the standardization activity due to this more specific focus. The result was that a standard was first developed to address classification systems in general (ISO 19144-1 Classification Systems) and then one to address LC (ISO 19144-2 Land Cover Meta Language). Both has been recently approved has official international ISO standards. The LCML (Land Cover Meta Language) is therefore a powerful toll to characterize geographic features in a more modern approach respect the conventional classification methods. Its intrinsic structure of open object oriented system allow not only an unambiguous description of real world features more consistent with the logic and structure of modern data bases but also enlarge the capability of the system to describe phenomena related to inputs and activities peoples undertake on a certain Land Cover feature typical of agriculture. A more detailed description of the LCML schema and some summary how it works is illustrated in annex 3.

2.2 A **new general framework for spatial data management**

The LCML derived classification system must be seen as only one component of a more composite framework of modern data management. If left alone it can have only a limited impact on the complex context of data standardization and harmonization. The table 1 below shows the different components (actions) of a modern spatial data management system.

Table1

ACTIONS	DETAILS	REALIZATION
REAL WORLD REPRESENTED WITH AN OBJECT ORIENTED LANGUAGE	Move standardization efforts from the class name to the definition of the rules and conditions to define a class	FAO has started this process in 1996 with the building up of the LCCS approach. The process has further strengthened with the realization of LCML (Land Cover Meta-Language) that has became in 2012 an ISO Standard
BUILDING UP OF NEW METHODS TO CAPTURE THE GRANULARITY OF INFORMATION OF THE REAL WORLD	A modern data base should avoid a strong generalization of complexity of the real world, on the opposite it should be able to capture as much as possible information. Those granularity of information do not necessarily need to be organized in traditional classes.	New methods are emerging but on the remote sensing and on field site. The adoption of LCML has ISO standard will enhance and structure the capabilities and potentials of these methods. New sensors like Sentinel 2 and the "Citizen Observatories" applications are good examples.
BUILDING UP OF A "RELATIONAL DATABASE".	The actual structure of geographic data bases mainly based on "shape" file format, are not ergonomic to manage data set organized by objects rather than classes.	The LCML language is perfectly suited by its object oriented nature to be organized in a "relational data base" like PostGIS or Oracle
USE OF LCML CONCEPT TO CREATE APPLICATION'S RELATED CLASSIFICATIO/NOMENCLATURES	The different classifications/nomenclature should be mainly built up to interrogate an object oriented data base to support specific applications.	The present nomenclature is the first operational example of this concept

The proposed data management system is composed by different components some of them already operative others in a dynamic evolving process. The underpinning of this system is the logic of representing real world features in an object oriented language with well defined and quantifiable attributes and characteristics. A big step on this direction has been the accomplishment of the FAO LCML (Land Cover Meta-Language) that has became an ISO standard in 2012. However other components are necessary to fully apply object oriented logic. Of vital importance are new methods and devices to capture the granularity of information of the real world features. Important potential advances in this sector are the launch of new sensors, the operational combination of different remote sensing devices, and the fast development of “citizen science” devices to upgrade with field observation remote sensing derived data. Directly linked with an “object oriented” description of the world feature is the development of a different way to store spatial information different from the shape file format. The use of a “relational data base” structure (PostGis, Oracle) seems to be the most ergonomic solution to enhance the LCML capabilities. The intrinsic logic of LCML seems to be fully compatible with this solution. Of course at the end of this process, there is the development of specific categorization systems which primary function should be the interrogation of a granular data base to give answers to specific applications see fig.3

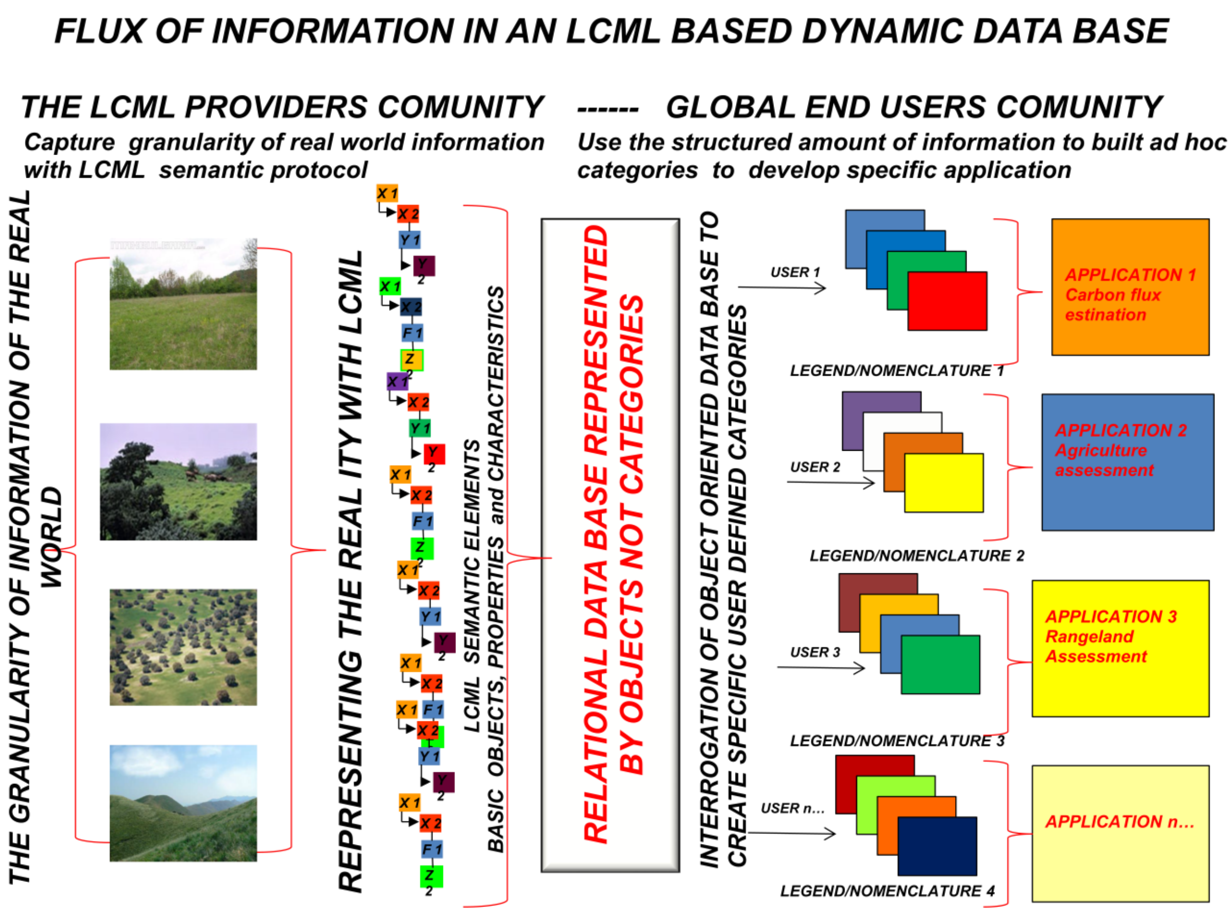


Fig. 3 the figure shows a schematic representation of the flux of information from the real world to a dynamic data base. The “object oriented” nature of the LCML system allow to potentially capturing the granularity of information of the real world. At this stage the data base can be populated by simple “objects” (enriched in their semantic meaning with specific quantifiable and measurable attributes and characteristics) and not necessarily by categories. However if categories are used at this stage of data information storage, they must have the quality to be decoded/converted in any moment into "objects" ("rendering voice retrieval" as explained in chapter 1.4). The conversion of the spatial data into a modern "relational "data base should allow an easy and unambiguous (mostly done in an automatic way) translation of the data set into specific nomenclatures (categories) created always with LCML rules and customized to respond to a specific application. The different nomenclatures are perfectly and understandably harmonized between themselves.

Chapter 3 the proposed Cropland Nomenclature

3.1 Major characteristics

POURPOSE: the present cropland categorization has been built up to possibly serve as reference to as many as possible, remote sensing based, categorizations of plant agriculture. It aims also to be a boundary entity to try to resolve the existing divergence between remote sensing derived cropland classes and the ones serving tabular statistic and in general derived from direct field observations. In addition the proposed system should be able to offers a definite base easy to be geographically located to which to link other aspects of agriculture of difficult spatialization.

THE UNDERLYING PRINCIPLES: the system is based on the logic of LCML (Land Cover Meta-Language, see annex 3) therefore the central components are derived from Land Cover and more in general from clear and quantifiable physiognomic/structural aspects of planted crops. Despite the large variety of actions human beings use in agriculture it is indisputable all these activities operate on a specific vegetation surface (cultivated plants). Using as base simple physiognomic and structural component s different cultivations can be separated on the base of the overall appearance (physiognomic aspect) of a crop and its spatial distribution pattern (vegetation structure or layering) in the field. The recurrence of the crop during certain unit of time (seasons or years) in a certain unit of cultivation space (the field) is another easy quantifiable classification element, together with the size of the fields itself and the presence/absence of other biotic or a-biotic elements in the fields (for instance natural vegetation, permanent structures as green houses etc.). These basic classification criteria can be then coupled with a larger variety of attributes (crop floristic aspect, crop cultural practices, crop growing parameters, crop fertilization, soil type etc.) to enlarge the thematic detail of a class.

THE FORMALIZATION OF THE MEANING: the overall structure of the system is represented in an UML schema. The schema shows the overall categories forming the system, their relationship and the extra attributes that can be eventually used to enrich the details of the classes. Furthermore for each class another UML schema is used to describe the structure of the class according to the reference LCML (Land Cover Meta Language) syntax. The overall logic of LCML implies that is more essential and functional to standardize the objects, rules and conditions determining a specific category rather than to converge the semantic meaning just on the final class name itself. The whole categories populating the present schema are in reality meta-classes, represented with specific unambiguous and measurable conditions able to clearly characterize a specific field situation. These meta-classes can be further refined with an open ended series of attributes.

3.2 **System design – main categories**

The detailed design structure of the system is expressed in an UML schema. The UML is a powerful modeling language capable to express with a modern and rational approach the whole different inheritance relationships between the different categories of the system and their interactions with several types of external characteristics. In addition, the objects, the rules and conditions to define each class of the proposed system is derived from the FAO LCML (Land Cover Meta-Language) that is itself described with an UML schema. The reference detailed "formalization of the meaning" of the whole proposed cropland nomenclature is fully described in annex 1were the main general UML and each class UML is fully described. However, because not everybody is fully familiar with the rules and the principle of an UML, in this chapter a more workable description is given using a classical text description of the rules and conditions governing the generation of each class. Not necessarily a simple text description will be able to fully systematically clarify the class meaning and the logic of the class boundary, ***therefore for a full application of the rules and conditions as well as the class relationship and the logic of the use of their attributes is always preferable to refer to the reference UML schema (annex 1).***
As above stated it is important to point out that in this "object oriented" system the semantic meaning is not any more focus on the class names, therefore the names are just "labels" to outline the detailed set of rules and conditions delineating the conceptual boundaries of a class.

The system considers different "levels" to define class boundaries and class characteristics; however these are "just" inheritance levels and not rigid partitions as in a classical hierarchical classification method. This implies that in a, system derived, local legend the user can use classes belonging to different levels in a fully unlimited way.

Main level: the separation between the two main categories is entirely related to the dominance of an Herbaceous versus a Woody crop (see fig.4)

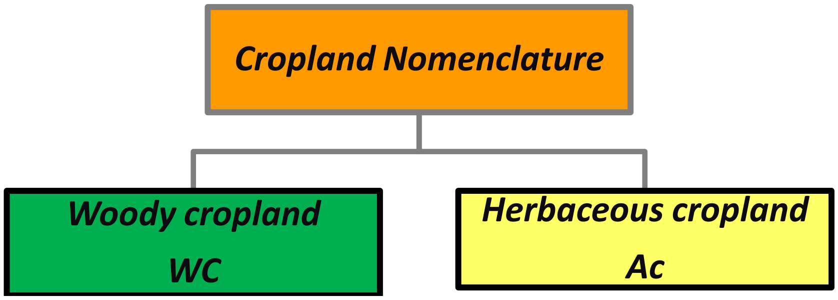


Fig.4

The broad definition of the two main classes is the following:

- ***Woody cropland***: an area with the presence of *cultivated and managed* woody crops with a cover % equal or more than 15%. Herbaceous crops as well natural woody vegetation can be optionally present. The definition of woody plant crop follows the LCML glossary definition (see annex 2). This class includes Forest plantations (cultivated and managed plantation of forest species).
- ***Herbaceous cropland***: an area dominated by *cultivated* herbaceous crops with a % cover equal or more than 15%. A certain presence of woody plants (cultivated or natural) can be optionally present, however the cover must be =< than 15%. This presence refers to woody plants spread in the cultivated field and do not refers to woody plants eventually used as field edging.

The definition of CULTIVATED area is conform to the LCML glossary and refers to:
Areas where the natural vegetation has been removed or modified and replaced by other types of vegetative cover of anthropogenic origin. This vegetation is artificial and requires human activities to maintain it in the long term. In between the human activities, or before starting crop cultivation, the surface can be temporarily without vegetative cover. Its seasonal phenological appearance can be regularly modified by humans (e.g. tillage, harvest, and irrigation). All vegetation that is planted or cultivated with intent to harvest is included in this class (e.g. wheat fields, orchards, rubber and teak plantations).

The present definition delimits the inclusion/exclusion of specific classes in this schema. Pastures, defined as areas devoted to the domestic livestock grazing, are in principle not active part of the system because in general the herbaceous plants remain basically natural vegetation. Some pasture related areas, however, are subject to a certain type of management and therefore , even if not fully part of the schema, are somehow directly linked with it and therefore explained and described with a specific UML (see fig . 5)

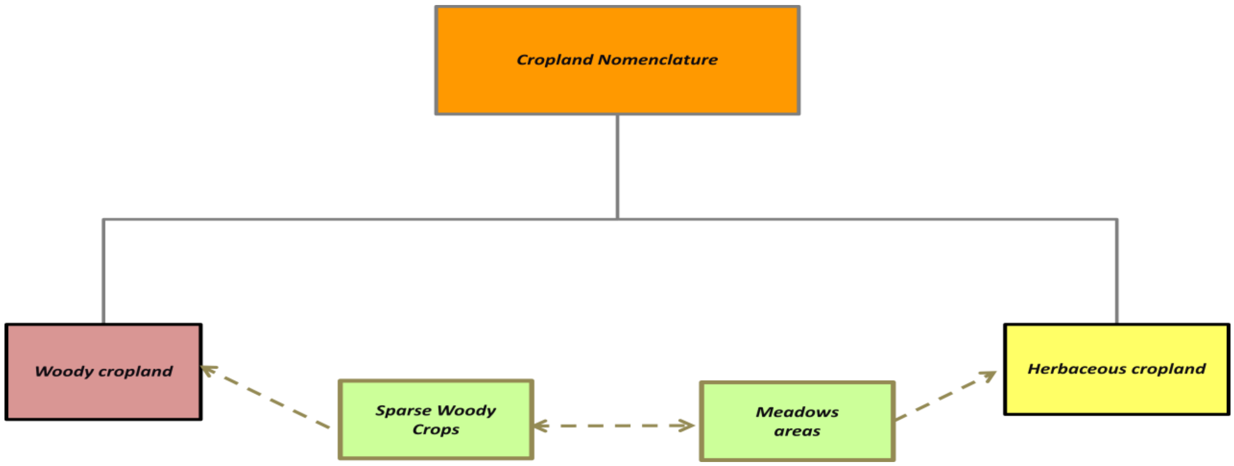


Fig.5

Meadows (or meadows type areas) are constituted by natural grasses; this vegetative cover cannot, therefore, be considered as a cultivated crop. The natural grass is, however, subject to the regular mowing of the plants that are later stored and used as forage for domestic livestock. Even if this activity cannot be fully included in a cultivation activity it is somehow directly related to it as explained in the system.
With the same logic ***Sparse Woody crops***, were the presence of woody crops is limited to sparse plants (cover < than 15 %) on natural herbaceous vegetation cannot really be considered an effective Orchard or Fruit plantation. However some old practices in central Europe can be closely (or almost closely) related to this field situation. In most cases these old practices combines the two situations above described, therefore some kind of sparse fruit trees can be found on Meadows areas. Both these field situations are described with a specific UML but are not considered categories fully belonging to the proposed system.

Further notes on the broad definition of herbaceous cropland: the clear separation of the classes in fig. 4 is extremely important because they from the two main categories from which all the other classes of the system are derived in a dichotomous arrangement. The optional presence of woody plants as component of the conditions defining the herbaceous cropland class needs, therefore, an extra statement. The condition of % cover at 15 % must be intended as a broad indication of presence of a woody vegetation layer that never assumes the character of dominance in respect to the herbaceous one. Therefore rather than a strict cover % value it should be considered by its overall appearance. When the woody layer is composed by woody crop the change of the “overall appearance” of the woody crop layer respect to the herbaceous one will determine the belonging to the class to the herbaceous or woody crop category. Different is the case of a woody natural layer, in this situation the 15% limit sharply define the belonging of a particular field situation to the present system or not. This value, therefore, has been careful tested to understand if it can be a threshold value to demarcate areas effectively dominated by herbaceous parkland cultivated areas. For sure minor cases can be found on which this threshold is not fully effective, however the many test done show that the majority of cases of parkland type of herbaceous cultivation fall into this range values (see fig 6,7,8,9, 10).

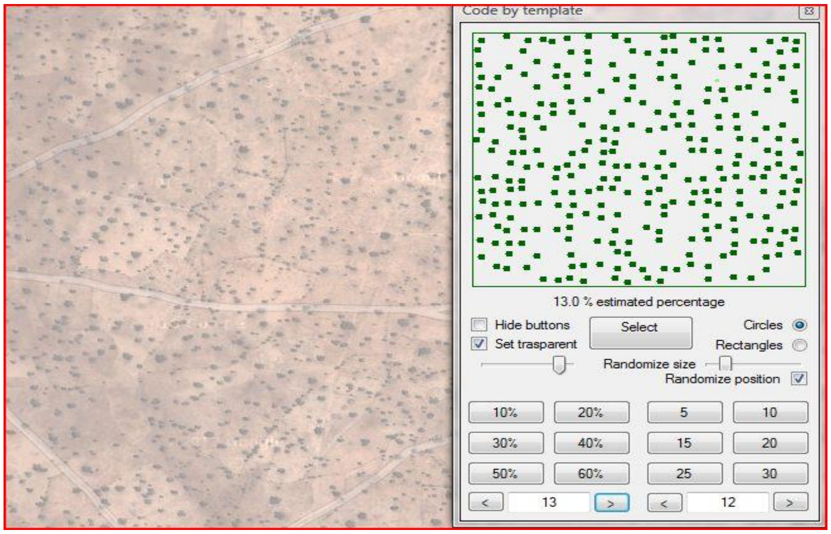


Fig. 6 central Senegal cover of natural woody vegetation of app. 13% with a crown diameter of 12 m.

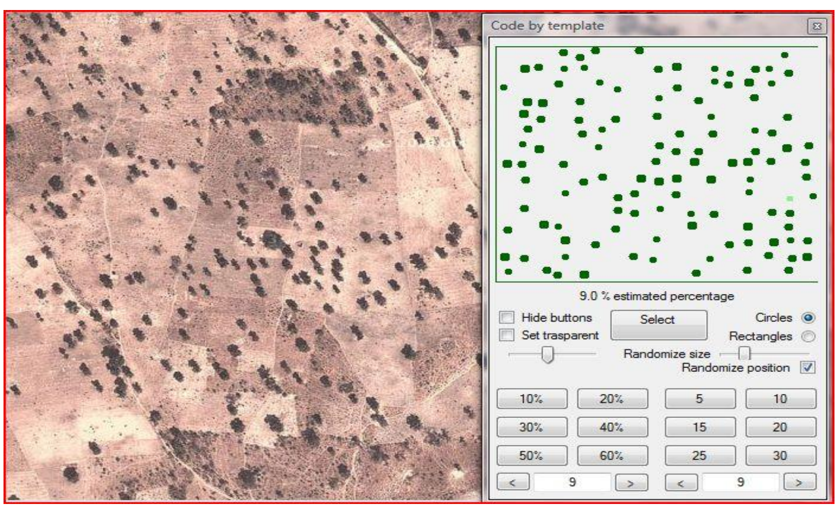


Fig. 7 central Bourkina Faso the cover of woody vegetation app. 9 % with a crown diameter of 9-10 m.

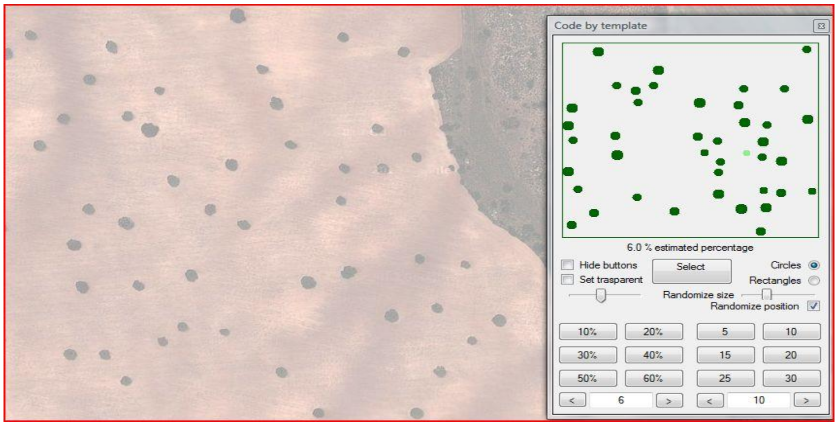


Fig.8 central Spain cover of the natural woody component around 8% with a crown diameter of app. 12 m.

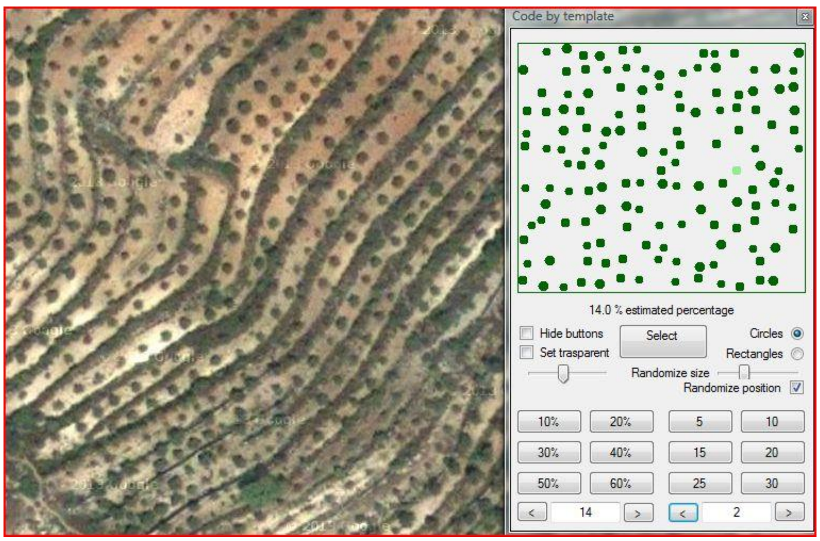


Fig. 9 South Lebanon, cover of app. 14% with a crown diameter of 2m., in this case, however, the woody plants are cultivated Olive trees and not natural vegetation.

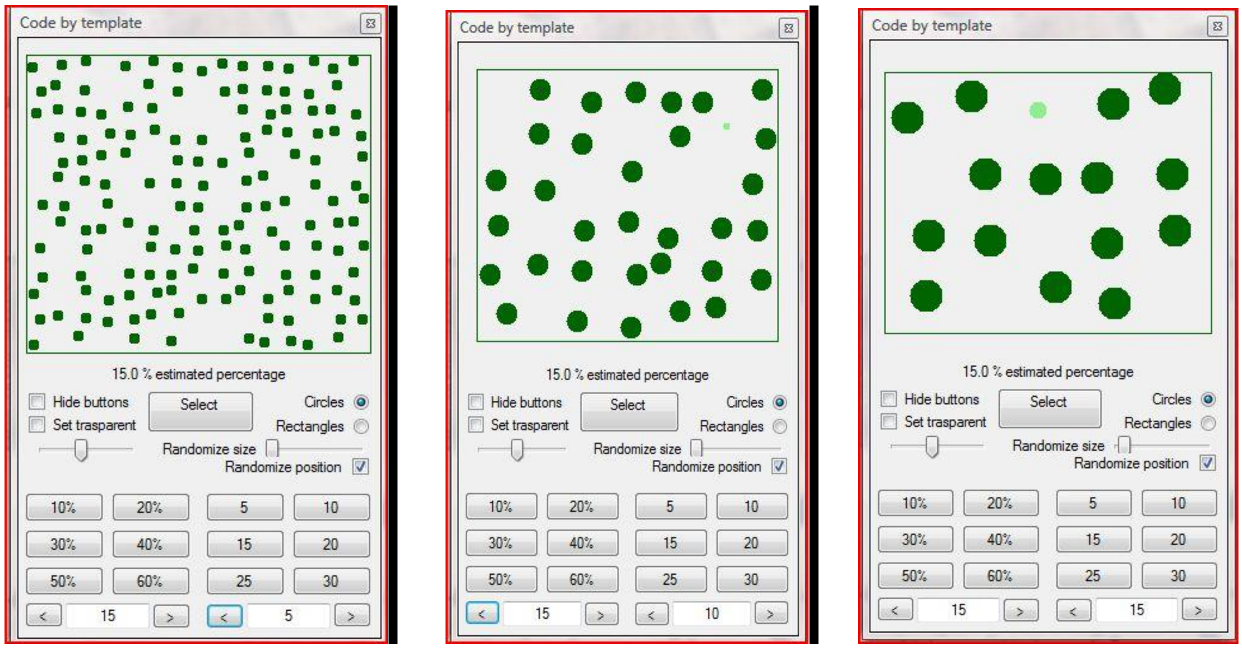


Fig. 10 shows the density of woody vegetation related to the crown diameter and % cover. The threshold 15 % seems to reasonably represent the maximum density level of woody vegetation that can be expected in a field situation representing a dominant herbaceous crop cultivation practice. The 15 % limit remains acceptable even in extreme cases when the crown diameter is set o a maximum of 15 m and therefore the woody density is reduced.

Second level: at this level the system further differentiate the classes according to their belonging to one of the two dichotomous nodes. In both case two categories are considered (see fig. 11):

- ***Orchards and other Plantations*** and ***Forest Plantations*** directly derive from the ***Woody cropland*** class. Both inherit the same general class definition. The further separation criteria between the two classes are mainly due to the differentiation between non forest woody species and forest species. The first one includes fruit trees and nuts including non forest species plantations (eg. Rubber plantation, Palm oil etc.) and shrub crops used for harvesting fruits, leaves etc, such as wine, cotton coffee, cocoa, tea, soft fruits etc. The second one includes typical forest species used for wood and non wood goods such as (Poplar, Pinus sp., Eucaliptus sp. etc). The definition of the ***Forest Plantation*** class relate to the official FAO definition (see glossary).

- ***Shifting cultivation*** and ***Permanent Arable cropland*** directly derive from the rules and conditions established for the ***Herbaceous cropland*** class. The main separation criteria are related to the “cultivation *time factor”* defined as: the time through the years or growing season (s) a certain portion of the land is covered by crops. Following this principle, in addition to the definition inherited from the higher node, Shifting ***cultivation*** is defined as: *the growing of crops for a few years on selected and cleared plots alternating with a lengthy period of vegetative fallow when the soil is rested. The land is, therefore, cultivated for less than 33% of the cultivation period.* On the contrary a ***Permanent Arable cultivation*** includes permanent and fallow herbaceous crops defined as: *an agricultural system with an alternation between a cropping period of several year and a fallow period where the land is cultivated from 33 to 66% of the year and/or for more than 66% in case of permanent cultivation.*

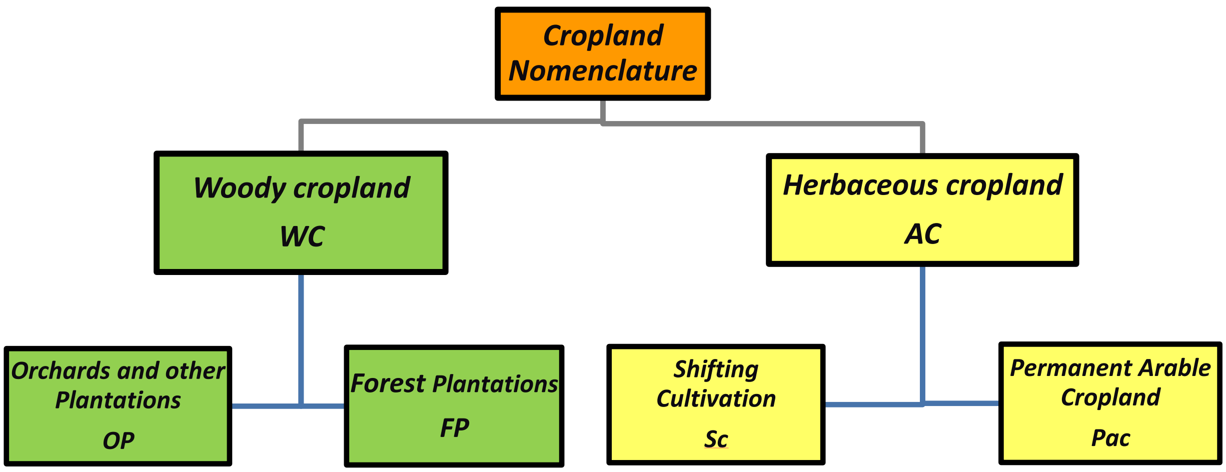


Fig. 11

Third level: in the dichotomous section of ***Woody cropland*** (see fig.12) the class ***Orchards and other Plantation*** further divides in:

- ***Trees Orchards and other Plantations***
- ***Shrub Orchards and other Plantations***

The main demarcation of these two classes is the separation of the woody plants in *trees* or *shrub* crops. This separation is based on the physiognomic appearance of the plants and is fully explicated in glossary. *Shrub Orchard and other Plantation* class includes also those non woody plants as Banana, Pineapple etc. due to their peculiar physiognomic appearance.

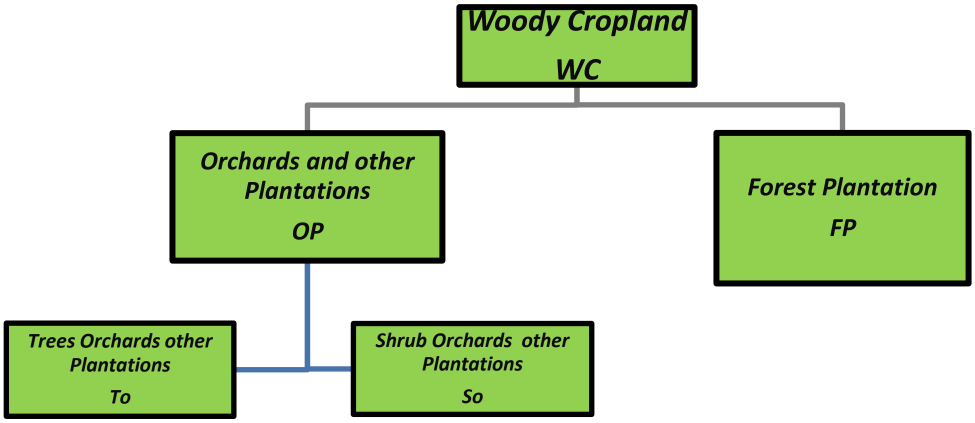


Fig. 12

The dichotomous section of ***Herbaceous cropland*** (see fig.13) further divides the ***Shifting cultivation*** class in:

- ***Shifting cultivation active fields*** that includes all the fields were during the current year (year of the observation) a crop has been cultivated.
- ***Shifting cultivation re- growth***, refers to areas were during the year of observation no crop has been cultivated and different stages of natural vegetation occur.

The ***Permanent Arable cropland*** further divides in:

- ***Wetland cultivation***: Areas were an aquatic crop is purposely planted, cultivated and harvested and which is standing in water over extensive periods during its cultivation time (e.g. Paddy rice, tidal rice and deep water rice). In general, it is the emerging part of the plant that is fully or partly harvested. Other plants (e.g. for purification of water) are free floating. They are not harvested but they are maintained.
- ***Herbaceous cultivation***: refers to the terrestrial herbaceous cropland rain fed or irrigated with or without a fallow period. A lower limit on field size (0, 4 Ha) has been put to demarcate this class from the next (*Small scale herbaceous cultivation*). Notice the *field size* parameter (e.g. field dimension) refers to the average size of the individual cultivated plots and not to the overall size of the farm holding.
- ***Small scale herbaceous cultivation***: the main characteristics of this class basically correlate with the previous class. The main difference is the field size that is small not exceeding 0, 4 Ha. This class includes all the different types of horticulture (confined or not) were the herbaceous crop is the dominant one (e.g. pulses and vegetables, flowers etc.). However this class includes also very small scale subsistence farming areas were different types of cereal crops are cultivated separately in very small plots (see fig. 14, 15, 16   ).

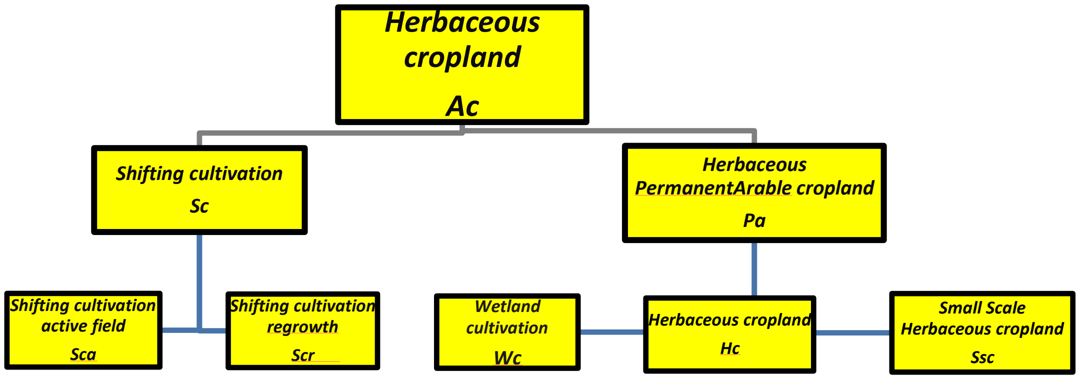


Fig. 13

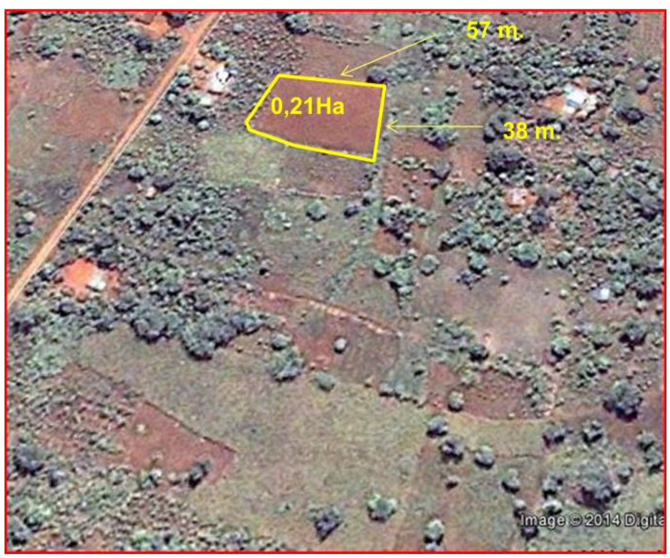


Fig. 14 central Uganda, plots were normally maize is cultivated.

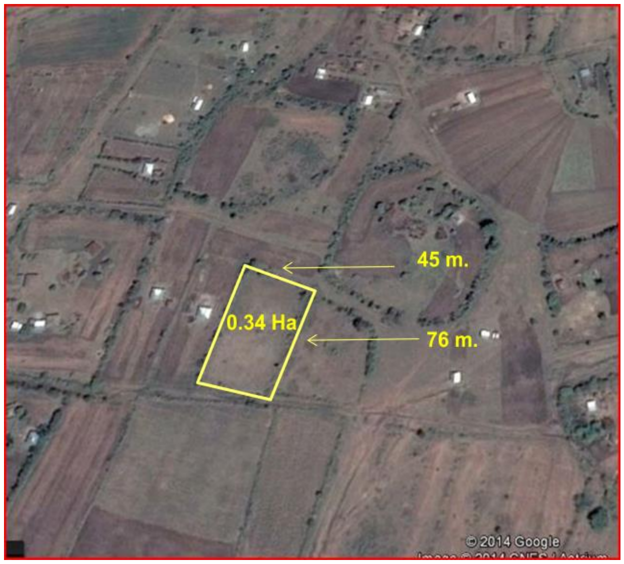


Fig. 15 central Kenya Kisumu area, plots with wheat and maize as dominant crop.

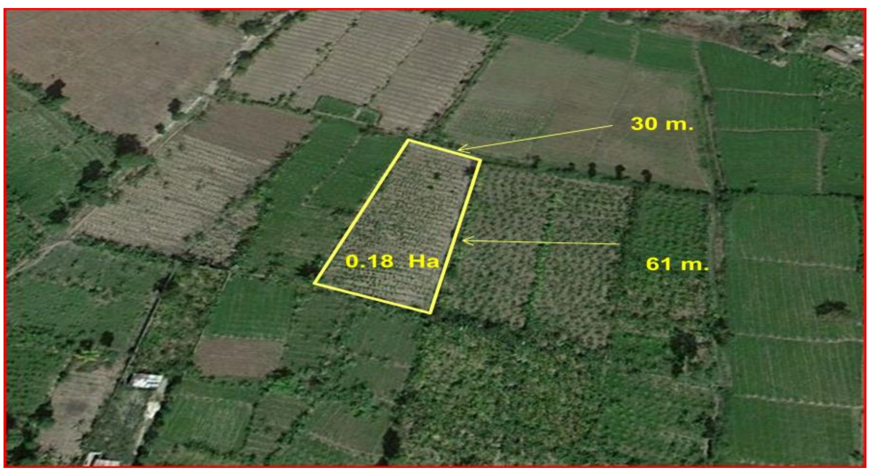


Fig. 16 Haiti, different types of crops can be cultivated on these small plots.

Fourth level: in this order both the ***Trees Orchards and other Plantation*** and the ***Shrub Orchards and other Plantations*** parallel divides in two further classes (see fig. 17) according to the presence/absence of another layer of herbaceous crops in addition to the tree and/or shrub crop layer. According to these conditions the classes are:

- ***Trees Orchards and other Plantations Monoculture***: no further herbaceous crop layer exists. The area is dominated by trees crops that can have (or not) a further layer of natural trees.
- ***Trees Orchards and other Plantation Intercropped:*** in addition to the dominant tree crop layer were the tree cover is more than 15%, another layer of herbaceous crops exist (e.g. oasis, olive plantations with winter wheat etc.)

- ***Shrub Orchards and other Plantations Monoculture***: no further herbaceous crop layer exists. The area is dominated by shrub crops that can have (or not) a further layer of natural trees.
- ***Shrub Orchards and other Plantation Intercropped:*** in addition to the dominant shrub crop layer were the shrub cover is more than 15%, another layer of herbaceous crops exist (e.g. vineyards with different types of herbaceous crops etc.)

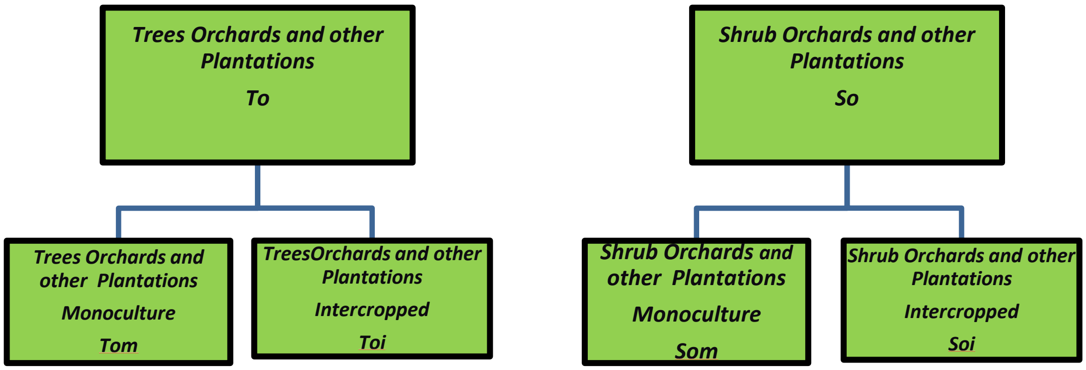


Fig. 17

At this level (see fig. 18) the class ***Shifting cultivation re-growth*** further divides in:

- ***Shifting cultivation herbaceous re-growth***: the re-growth in this case is limited to natural herbaceous vegetation indicating that only few years from the last active cultivation phase.
- ***Shifting cultivation woody re-growth***: the re-growth is mainly constituted by shrubby vegetation, indicating a longer period of inactive cultivation phase.

The class ***Herbaceous cropland*** further divides in:

- ***Herbaceous cropland open***: it inherit the basic conditions of the Herbaceous cropland, the only difference is that no significant natural woody natural vegetation is present in the fields (natural woody cover less than 3 %)
- ***Herbaceous cropland layered***: on the contrary this class presents a conspicuous presence of natural woody vegetation up to 15% cover.

The class ***Small scale Herbaceous cropland*** further divides in:

- ***Small scale Herbaceous cropland open***: it refers to open fields with no structures like green houses or similar.
- ***Confined Herbaceous horticulture***: specifically refers to different types of herbaceous horticulture confined in permanent of semi-permanent structures (green houses, plastic tunnels etc.)

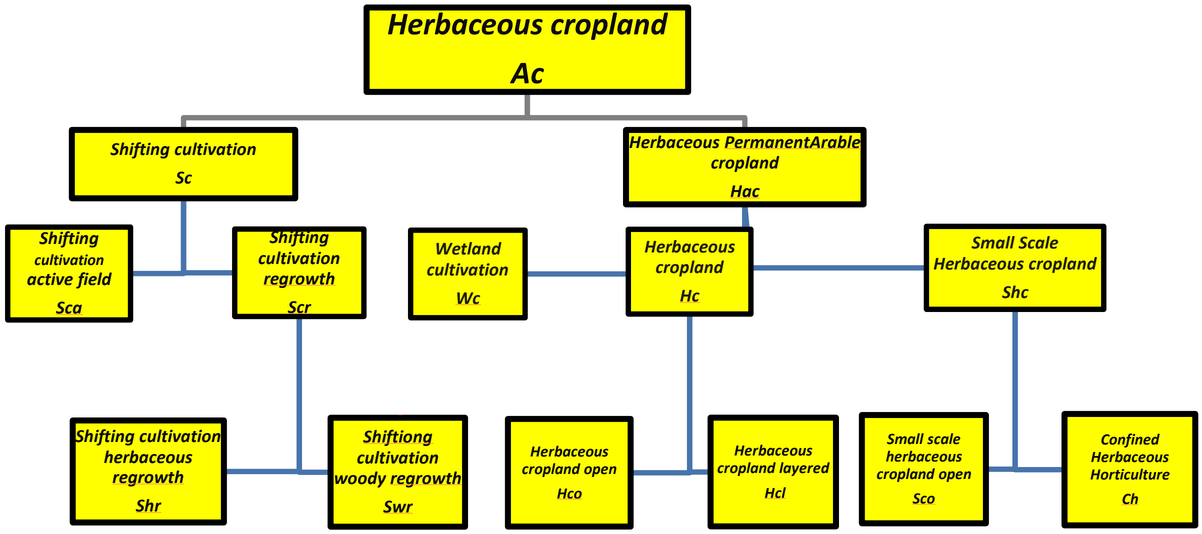


Fig. 18

A ***Fifth and Sixth*** level exit for some classes to further refine or make evident some extra structural aspects of the cultivated plant crops. For the trees or shrub orchards and other plantations classes this results in the following (see fig. 19):

- ***Trees Orchards other Plantations single layer***: trees crop cultivation without any extra layer of natural trees.
- ***Tress Orchards other Plantations shadowed***: a trees crop cultivation shadowed by an additional natural tress layer.
- ***Trees Shrub Orchards other Plantations intercropped***: a specific situation were three different strata of crops exist; trees and shrub crops over an herbaceous cultivation, usually irrigated (e.g. some old variety of desert date palm oasis etc.).

- ***Shrub Orchards other Plantations single layer***: a shrub crop cultivation without an extra layer of natural trees.

- ***Shrub Orchards other Plantations shadowed***: a shrub crop cultivation shadowed by an additional layer of natural trees.

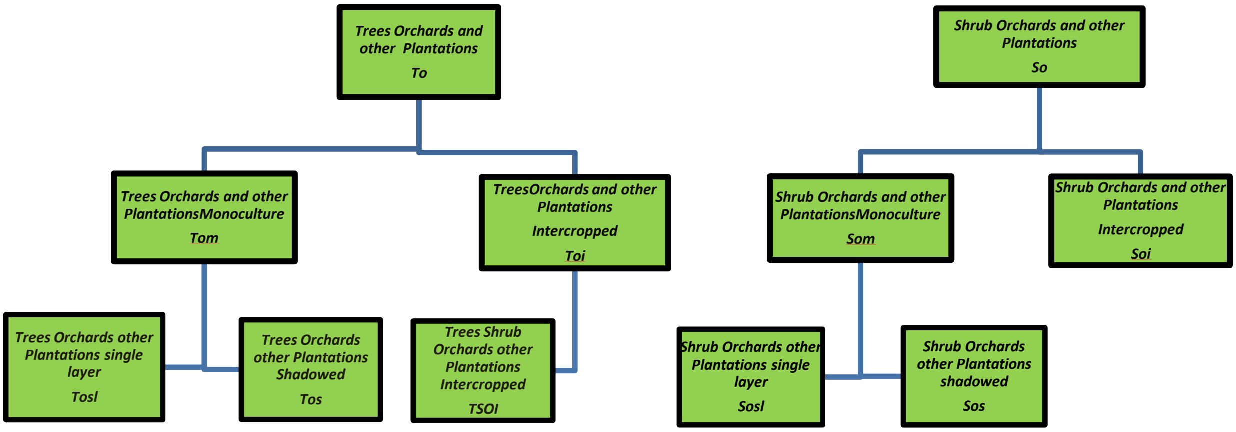


Fig. 19

For the herbaceous cropland, the class ***Herbaceous cropland layered*** further divides (See fig.20) according to the type of the extra woody vegetation layer in:

- ***Herbaceous cropland trees layered***: herbaceous crops with a consistent presence of natural trees (cover range 4-15 %)
- ***Herbaceous cropland shrub layered***: herbaceous crops with a consistent presence of natural shrubs (cover range 4-15 %)

The class ***Small scale herb. cropland open*** further divides according to the presence/absence of an additional layer of woody vegetation in:

- ***Small scale herb. cropland single layer***: the herbaceous crop do not have any (or negligible less than 4% cover) of natural woody layer.
- ***Small scale herb*. *cropland layered***: the herbaceous cropland has a consistent (cover from 3-15%) presence of natural woody plants. This class in the next level further divides according to the type of woody plants present in: ***Small scale herb. cropland trees layered*** and ***Small scale herb. cropland shrub layered***.

Finally the class ***Confined herbaceous horticulture*** further divides according to the type of horticulture structure in:

- ***Temporary structures confined herbaceous horticulture***: the structures were the cultivation take place are temporary or semi-permanent (e.g. plastic tunnels etc.)
- ***Permanent structures confined herbaceous horticulture***: the structure is a permanent one as a typical green house.

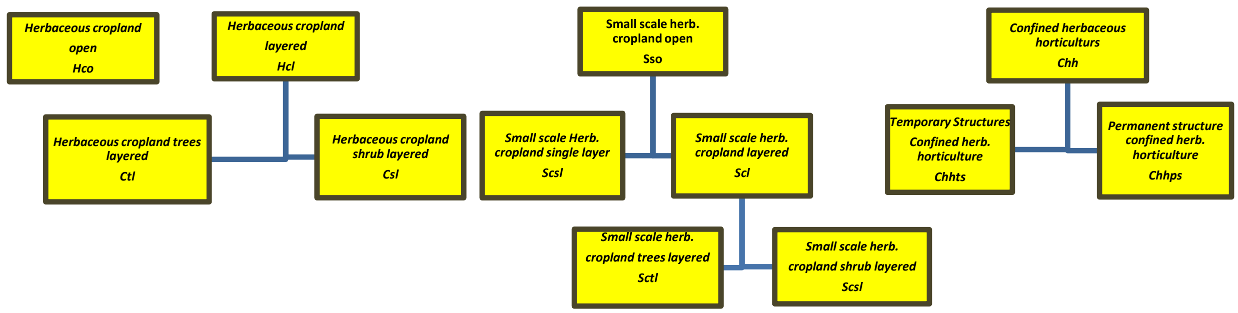


Fig. 20

3.3 ***System design- extra class attributes***

The categories represented in the system should be considered in reality as meta-classes, a kind of broad set of specific field cropping conditions regulated by a series of specific rules and conditions. However these meta- classes can be further (optionally) refined using a large series of class *attributes* called in the UML schema *characteristics*. The UMl schema clearly lists their distinctive properties and indicates at which level of the system each *characteristic* will operate. Below, these *characteristics* are specified in simple lists grouped according to the level and class type they are acting on. It is important to specify the lower classes in the system will inherit also the characteristics from the class from where they derive from.

Main level: three main types of *characteristics* are present:

- The ones in common to both **Woody cropland** and **Herbaceous cropland** classes
- The ones related only to **Woody cropland** class
- The ones related only to **Herbaceous cropland** class

Characteristics common to both ***Woody cropland*** and ***Herbaceous cropland*** classes:

- ***Climate***: the present climate attribute is classified according to the Agro-Ecological Zoning as developed by FAO using two items: *thermal climate* and length *of growing period* (see glossary). However other methods can be used if clearly stated in the user attribute's annex.

- ***Topographical aspects***: limited to *altitude* expressed in a range value in meters and *slope* expressed in a range value in degree
- ***Soil characteristics***: limited to *soil types* (according to FAO soil classification) and *erosion types* (listed in the glossary).
- ***Water supply period***: defined in *irrigation types* (see list in the glossary) and *irrigation percentage* expressed in % range values
- ***Field size***: defined as *field size types* (see lest in glossary) and *field size* expressed in range value in meters.
- ***Crop fertilization***: expressed in *fertilization types* (see list in the glossary) and *fertilization frequency* expressed in range value in months.

Characteristics related to ***Woody cropland*** class:

- ***Woody growth form characteristics*** as: *plant spreading geometry types (see glossary), growth form age* calculated in years, *growth form age types* (see glossary) and *crown diameter* expressed in a range value in meters.
- ***Woody plant types***: indicated in *species broad categories* (see glossary) *floristic species name*.

Characteristics related to Herbaceous ***cropland*** class (the following characteristics are also additionally linked to the herbaceous cropland component of the ***Trees orchards and other plantations intercropped*** and ***Shrub orchards and other plantations intercropped*** classes in the ***fourth level***):

- ***Crops cultural practices***: expressed in *erosion control types* (see list in the glossary) *crop combination types* (see list in glossary), *pest control types* (see list in the glossary), *pest control frequency* expressed in range value in months, *ploughing types* (see list in glossary), *ploughing frequency* expressed in range value in months.
- ***Crop growing parameters***: including *seeding time*, *growing length* both expressed in range value in months, *overlap growing* expressed in % range value, *crop combination* (see list in glossary), *crop number* expressed in real number value.
- ***Herbaceous plant types***: indicated in *species broad categories* (see list in glossary), *floristic species*.

Second level the following characteristics are present:

Characteristics related to ***Forest plantation*** class:

- ***Rotation cycle***: expressed in *rotation type* (see list in glossary), *rotation years* expressed in range value in years.

Characteristics related to ***Orchards and other plantations*** class:

- ***Horticulture***: expressed in *horticulture types* (see list in glossary).

Characteristics related to ***Permanent arable cropland*** class:

- ***Active fields***: defined as the areas were during the observation time a crop has been cultivated.

Third level the following characteristics related to the ***Wetland cultivation*** class:

- ***Water body periodic variations***: expressed as *period type* (see list in glossary), *persistence type* expressed in real number and defined in *persistence unit* defined in unit types (year, month, day or hours).
- ***Water deepness***: expressed as *deepness types (list in glossary)*
- ***Aquaculture***: expressed as *aquaculture types* (see glossary)

Fourth level the characteristics are related to different classes:

Herbaceous cropland layered class:

- ***Woody vegetation artificiality***: expressed as *vegetation artificiality type* (cultivated or natural/semi natural)

Small scale herbaceous cropland open class:

- ***Horticulture***: expressed as *horticulture types* (see list in glossary)

Confined herbaceous horticulture class:

- ***Hydro culture***: expressed as *hydro culture types* (see list in glossary)

Fifth level the characteristics are related to ***Open small scale cropland layered*** class (specifically to the woody layer present):

- ***Woody vegetation artificiality***: expressed as *vegetation artificiality type* (cultivated or natural/semi natural).

Annex 1 the Cropland nomenclature UML schema

The schema is composed by the main nomenclature categories that are ordered according to their inheritance levels. The use of an UML schema to represent the overall nomenclature logic has been adopted for the following reasons:

- The use of a modern modeling language relates to the dynamic of science in the representation of geographic features.
- A UML is able to give an overall detailed and straightforward overview of all the relationships between the system categories.
- With the logic of an UML is possible to define the conditions and levels were extra attributes acts to further detail the system classes.
- The rules and conditions defining each of the main categories populating the system are derived from the new FAO LCML (Land Cover Meta-Language) that is itself described in another specific UML.

The categories of the system should be considered as meta- classes; practically they define the broad major characteristics that define a specific portion of the ground. However these categorizations can be further refined by a series of attributes that are selectively linked at different nodes levels in the UML. The use of the attributes will extend the details of this specific nomenclature to fit with the majority of the situation of the real world.

The fig. 21 shows the overall components of the model, they adhere to the following logical system's sequence:

- The cropland nomenclature is composed by many cropland classes.
- Each cropland classes are built up with the LCML syntax.
- Each cropland class can be further enriched by specific characteristics (the LCML characteristics).
- The LCML characteristics are part of the present LCML register.
- Different cropland nomenclature classes (with or without other non cropland classes) can represent a more complex agriculture situation called " Agriculture Functional Unit".

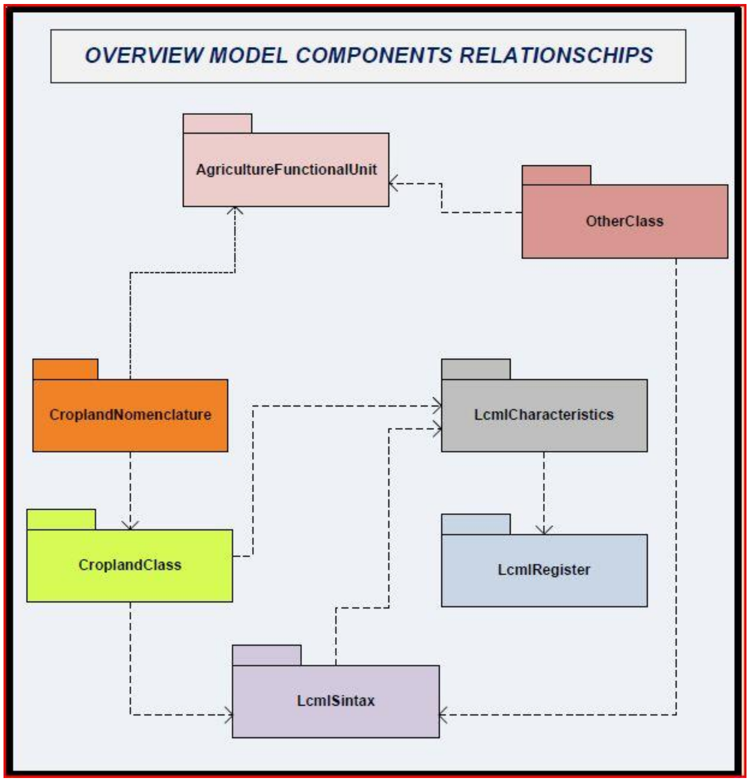


Fig. 21

The fig. 22 shows the overall structure of the UM L., while fig. 23 shows the portions (red boxes) of the UML enlarged for a better view of the schema.

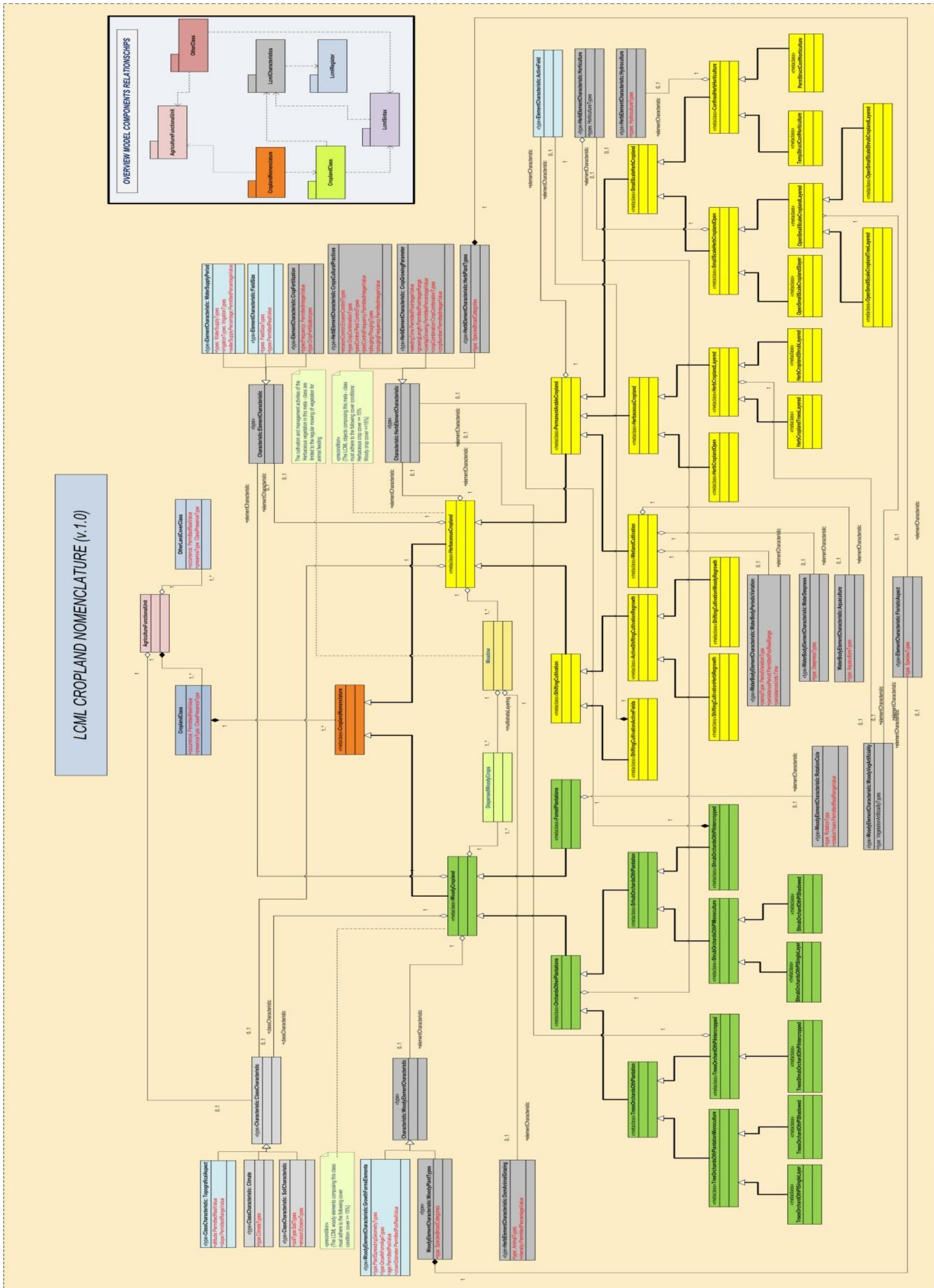

LCML CROPLAND NOMENCLATURE (v.1.0)
OVERVIEW MODEL COMPONENTS RELATIONSHIPS

Fig.22

Fig.23 for a better understanding the UML schema is shown in different enlargements boxes.

Fig. 24 is the enlargment of the UML portions as shows in box 1 of fig. 23.

The portion of the UML enlarged in box 1 illustrates two different aspects of the system:

- How to built a more complex “Agriculture Functional unit” starting from cropland categories. As “*Agricultura Functional unit”* is intended a more complex arrangment of farming enterpreses that could be the starting point for the geographic delineation of the more complex concept of *“Farming system”.* The schema, at this specific level, illustrate how one or more cropland nomenclature classes eventually coupled with other non cropland classes can form a complex unit. Each category (cropland and non cropland) has two attributes “*Occurrence”* expressed in % real value range, and *“Presence type”* expressed according to specific types (*mandatory, optional, exclusive*) which meaning is detailed in the glossary. Using these attributes linked to various combinations of categories a detailed modelling of real field cases is possible.

- The first two major categories differentiating the whole system. Each category of the schema is fully explained in other sub- schemas that use the LCML language elements as shown in fig. 25, 26.

- The shema describes the type of relationschip that categories as “*Meadows”* and *“Dispersed Woody crops”* have with the major cropland classes and between themselves.

The fig. 25 and 26 show the conditions to define the first two classes of the system according to the LCML rules. The LCML structure defining the class is higlighted by a dotted box.The upper and lower part of the figure shows the inheritance levels of each category. The whole set of *“Characteristics”* that can be used to enrich the class meaning are shown at each node of the schema (the blu boxes of the *Characteristics* indicate the ones that potetially could be extracted from remote sensing). The definition of the *“Characteristics”* (woody, herbaceous or element) is set to facilitate a future translation of the system in a *relational data base language* (Oracle, PostGres) indicating to wich UML object they must be linked.

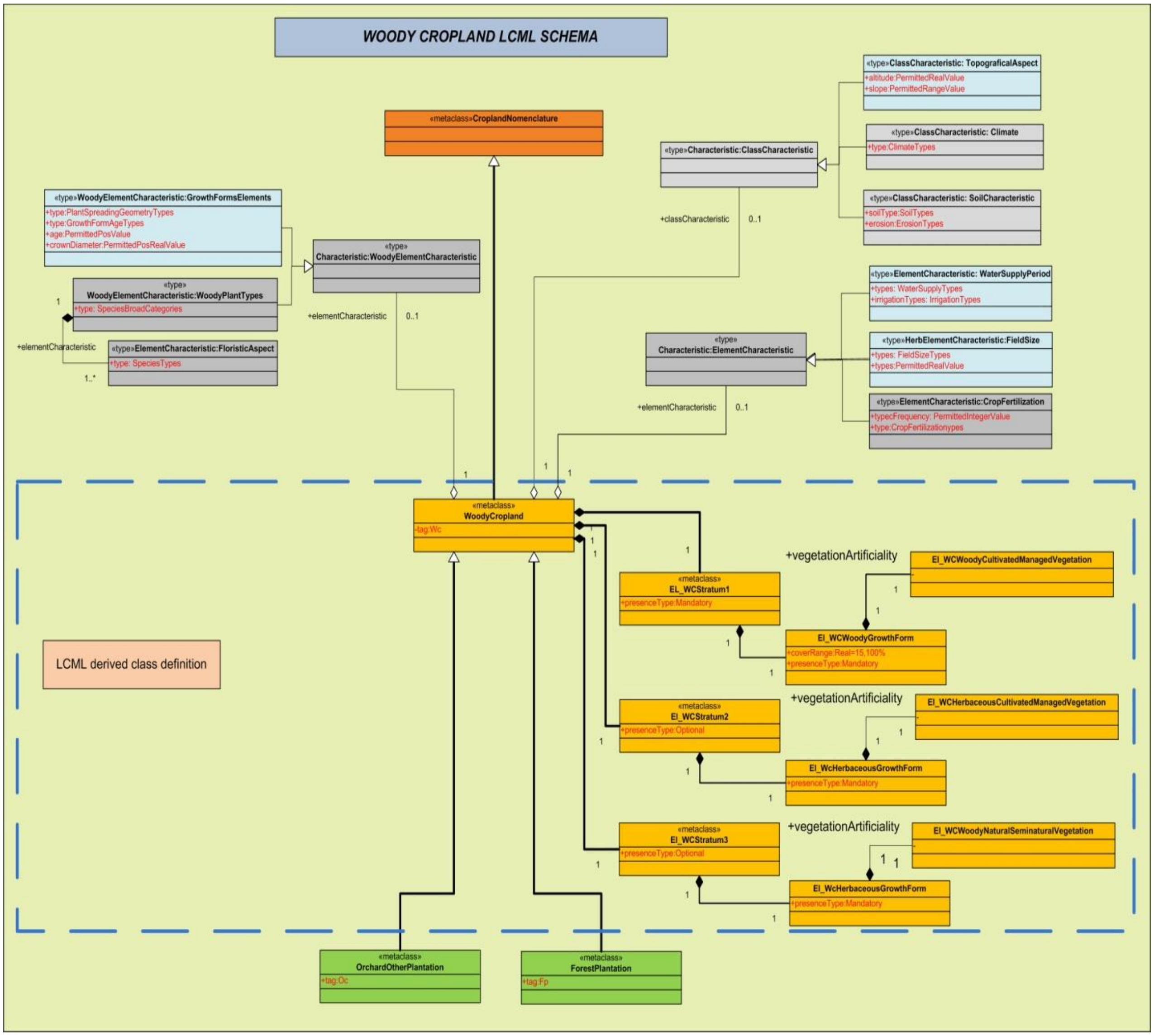


Fig. 25 UML schema of the class Woody cropland.

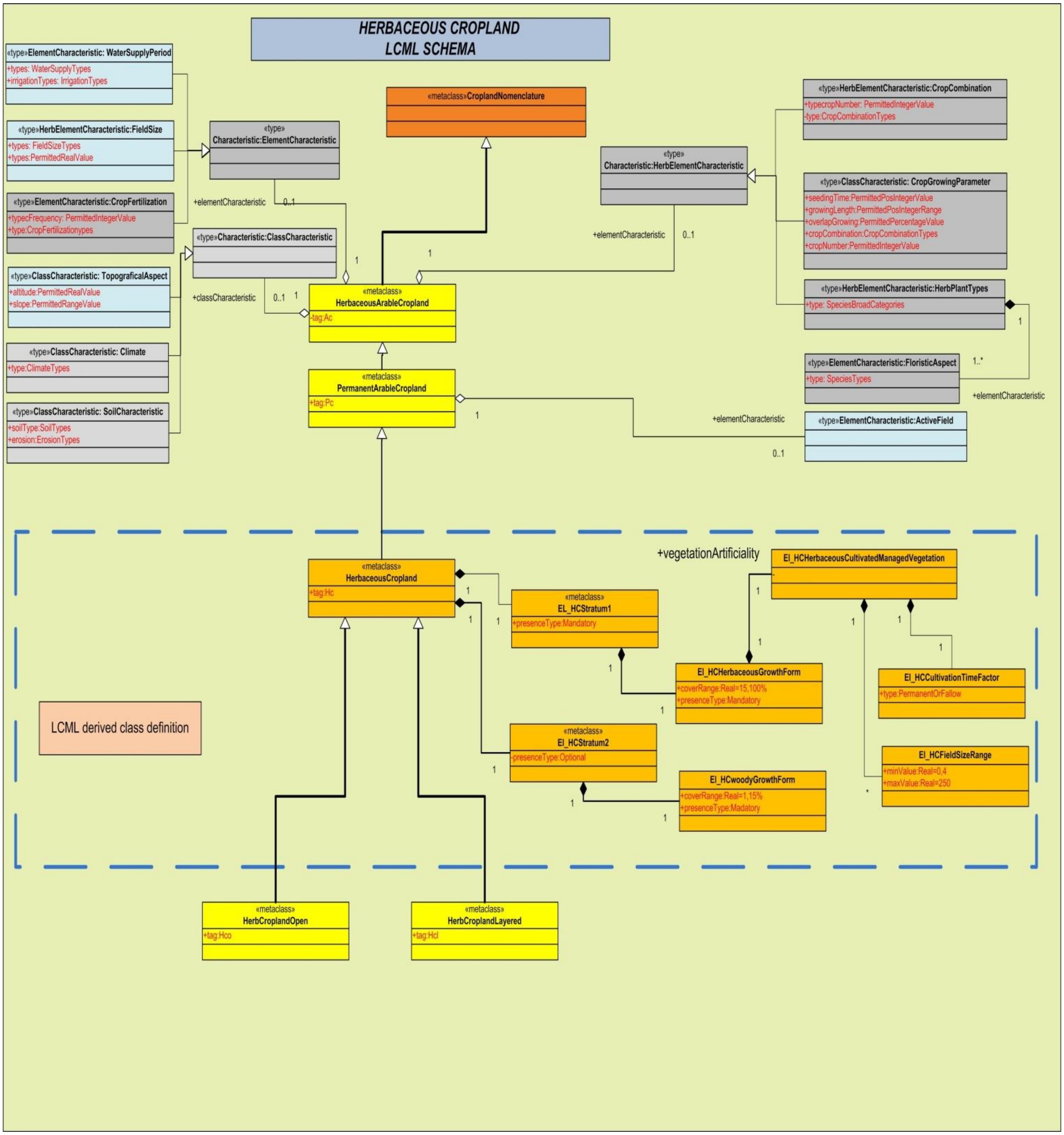


Fig. 26 UML schema of the class Herbaceous cropland

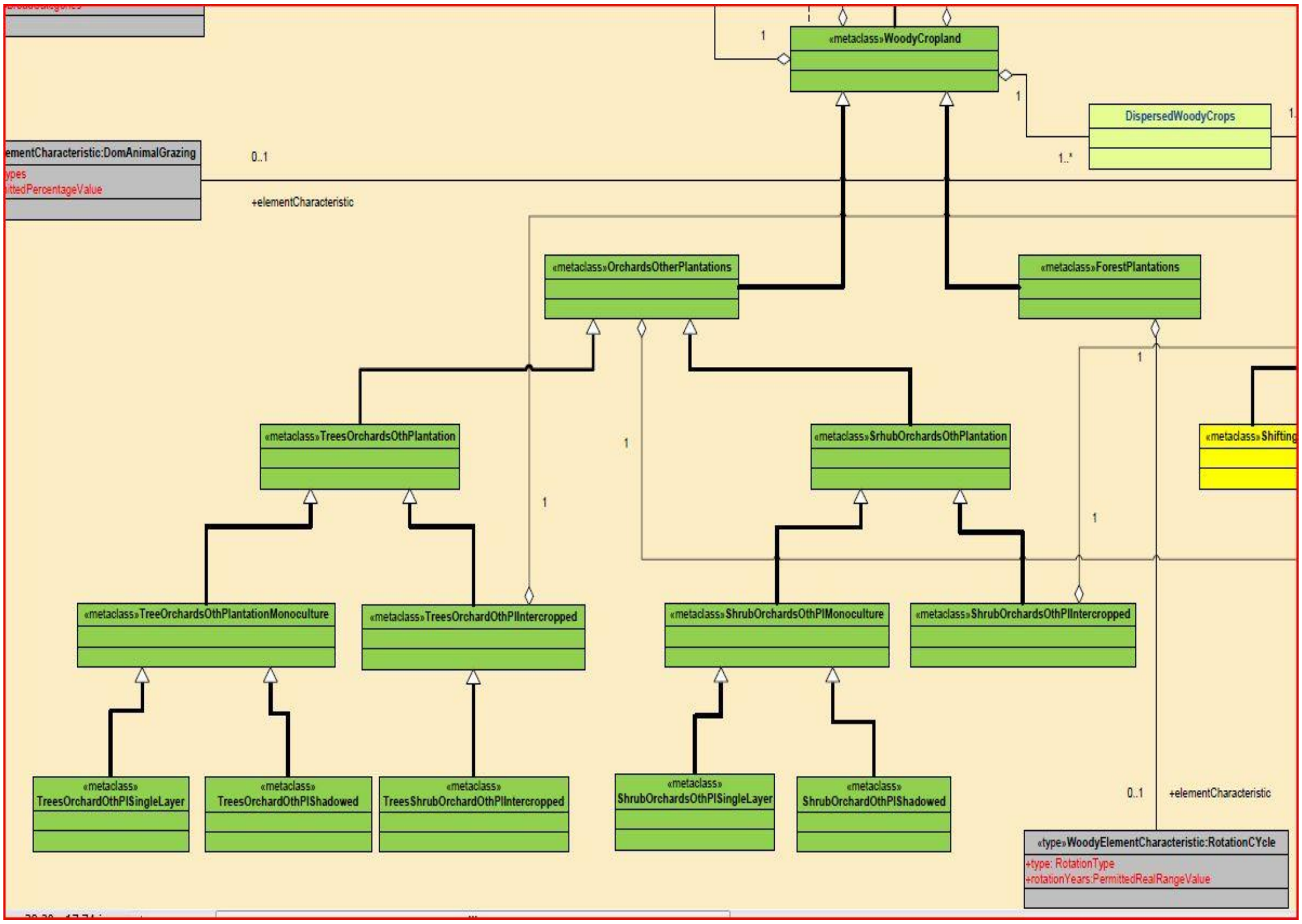


Fig. 2 7 shows the box2 of the UML, were all the classes derived from the Woody cropland category are explained in their relationships and inheritance.

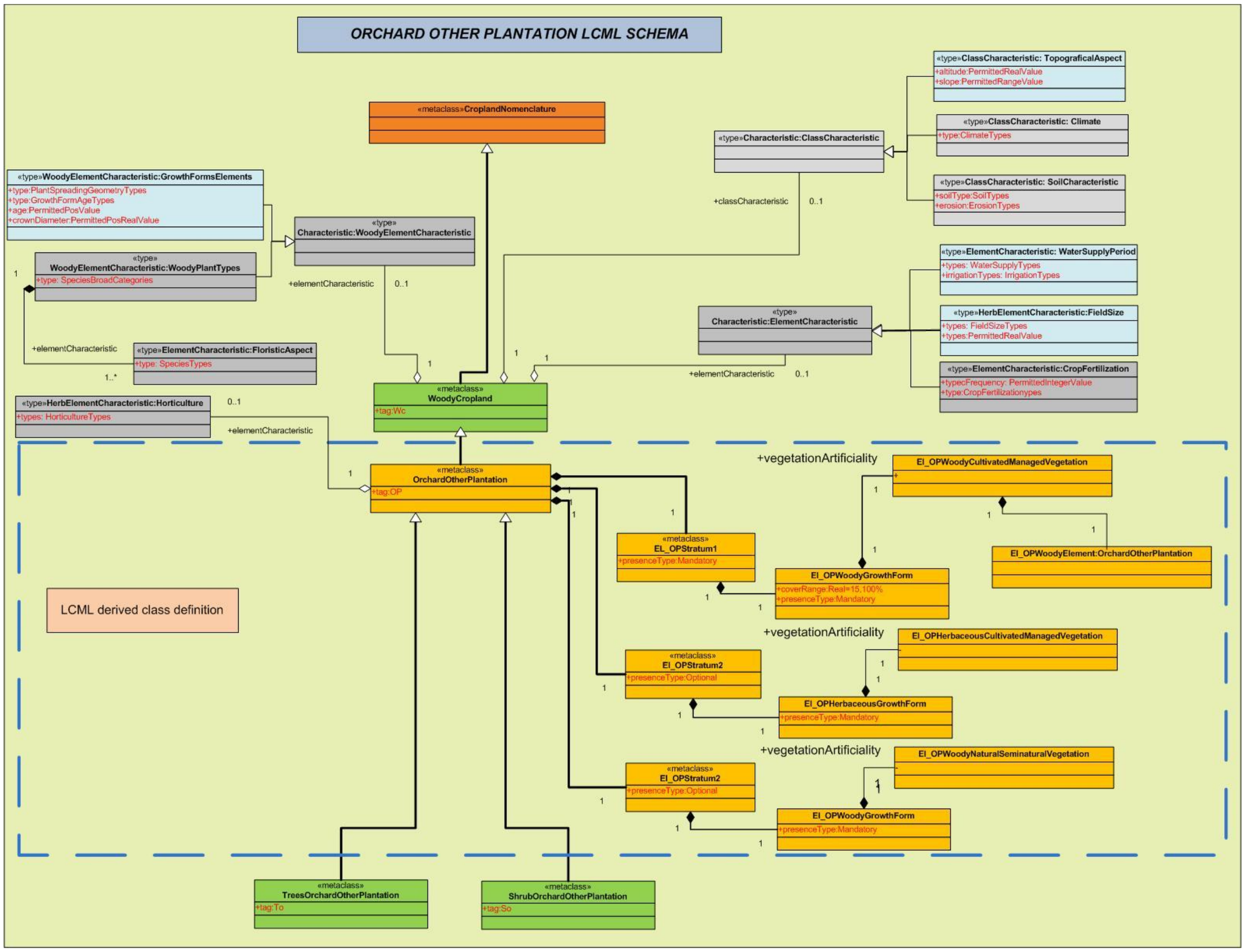


Fig. 28 UML schema of the class Orchards and other Plantations

In this case the main condition governing the utilization of this class is the presence of a strata of Woody cultivated and managed vegetation; a basic plant cover % attribute is present and is set to => 15%. At this level of class generalization no distinction is made between a further physiognomic aspect of woody plants (trees, shrubs). The mandatory characteristic: *Orchards and other Plantations* definitely specify the broad origin of the woody vegetation constituted by fruit and similar types of plants (see glossary). Optionally other strata respectively of herbaceous crops and natural trees can be present to represent a wide variety of cases that this general class is intended to represent.

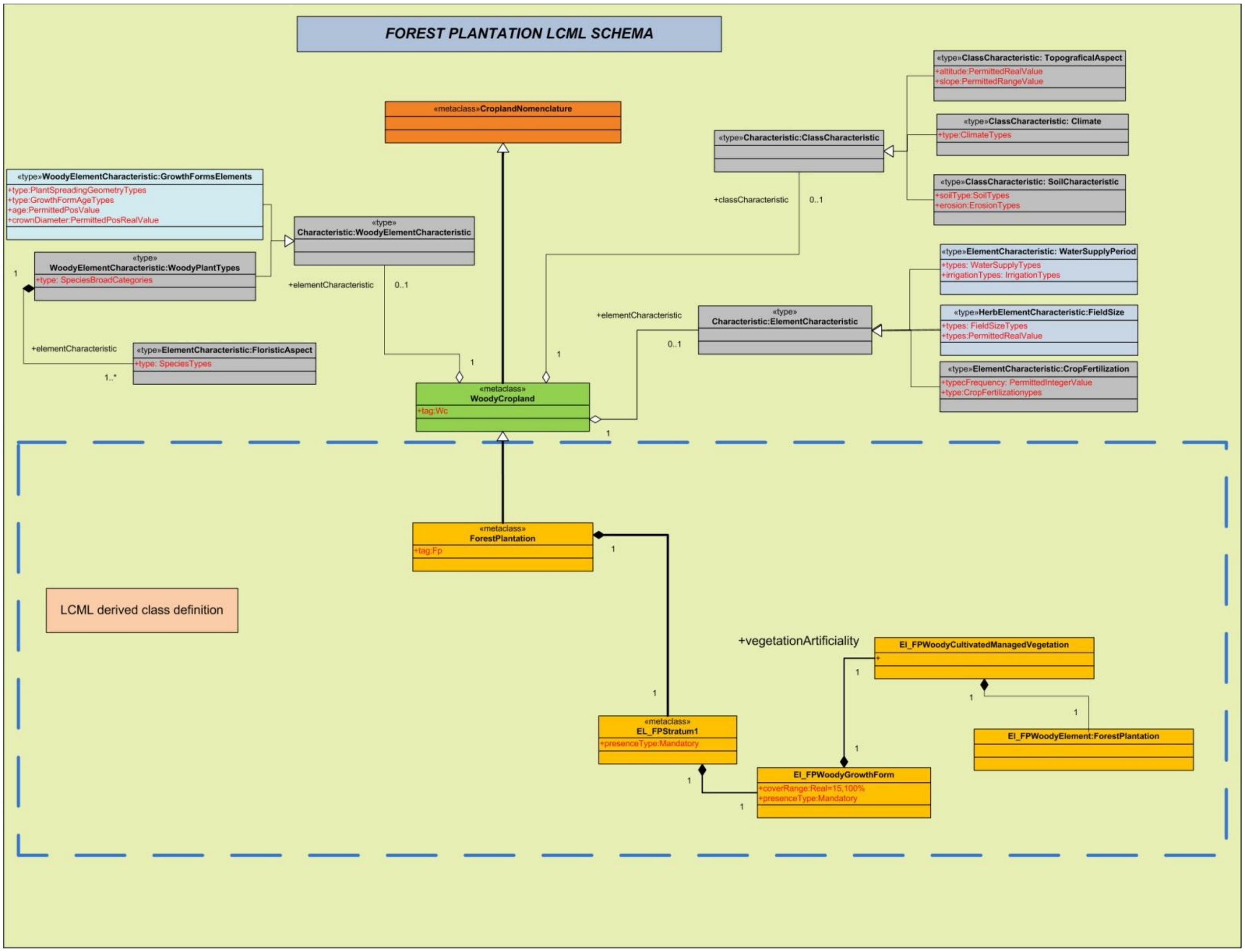


Fig. 29 UML schema of the class Forest Plantations

In this case the main conditions governing the utilization of this class are very simple:

- the presence of a strata of Woody cultivated and managed vegetation; a basic plant cover % attribute is present and is set to => 15%.
- The mandatory characteristic: *Forest Plantations* definitely specify the broad origin of the woody vegetation constituted by forest plants used mainly for the wood production(see glossary).

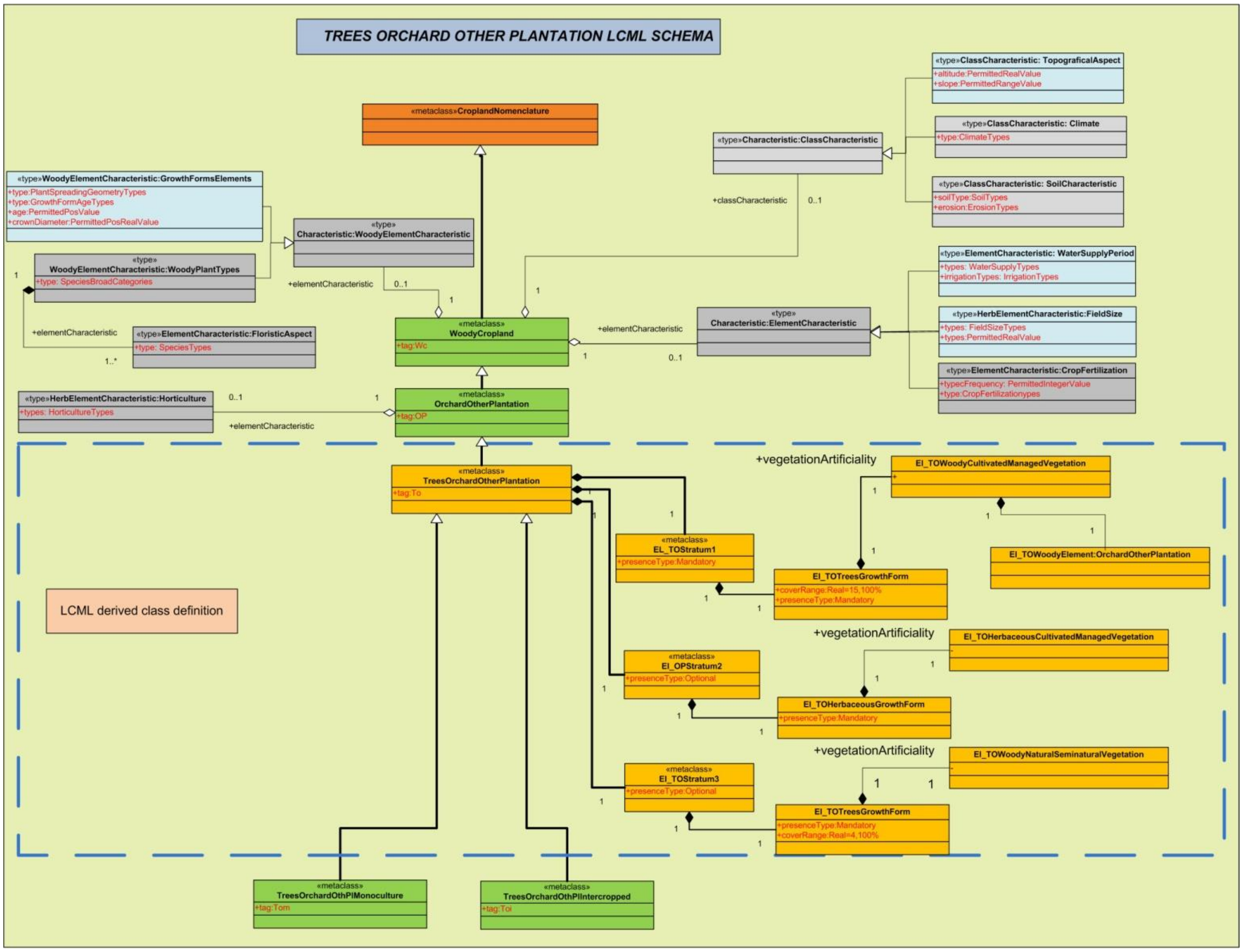


Fig. 30 UML schema of the class Tree orchards and other Plantations

In this case the main conditions governing the utilization of this class are similar to the higher node of the schema (Woody orchards and other plantations fig.29) the only important difference is that the main strata is characterized by Trees cultivated and managed vegetation; the plant cover % attribute remains set to => 15%. The mandatory characteristic: *Orchards and other Plantations* definitely specify the broad origin of the woody vegetation constituted by fruit and similar types of plants (see glossary). Optionally other strata respectively of herbaceous crops and natural trees can be present to represent a wide variety of cases that this general class is intended to represent.

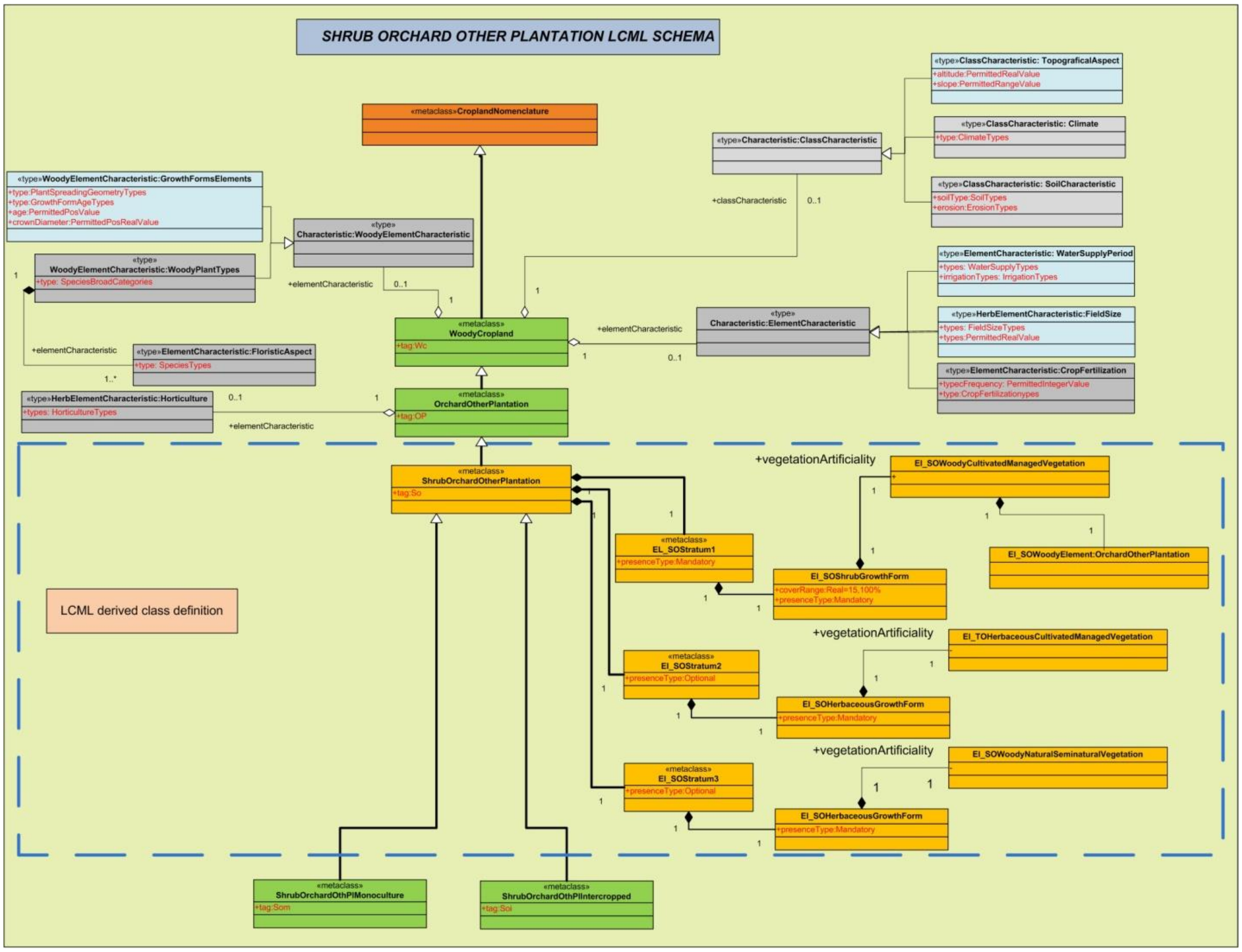


Fig.31 UML schema of the class Shrub orchards and other Plantations

This class derives (as for Trees orchards and other plantations) derives from the higher node of the schema (Woody orchards and other plantations fig.29) therefore the decisive difference is the presence of a strata of Shrub cultivated and managed vegetation; the plant cover % attribute is still set to => 15%. At this level this class, together with the class Trees orchards and other plantations delimit a dichotomous further separation of tree or shrub crop specialized classes.

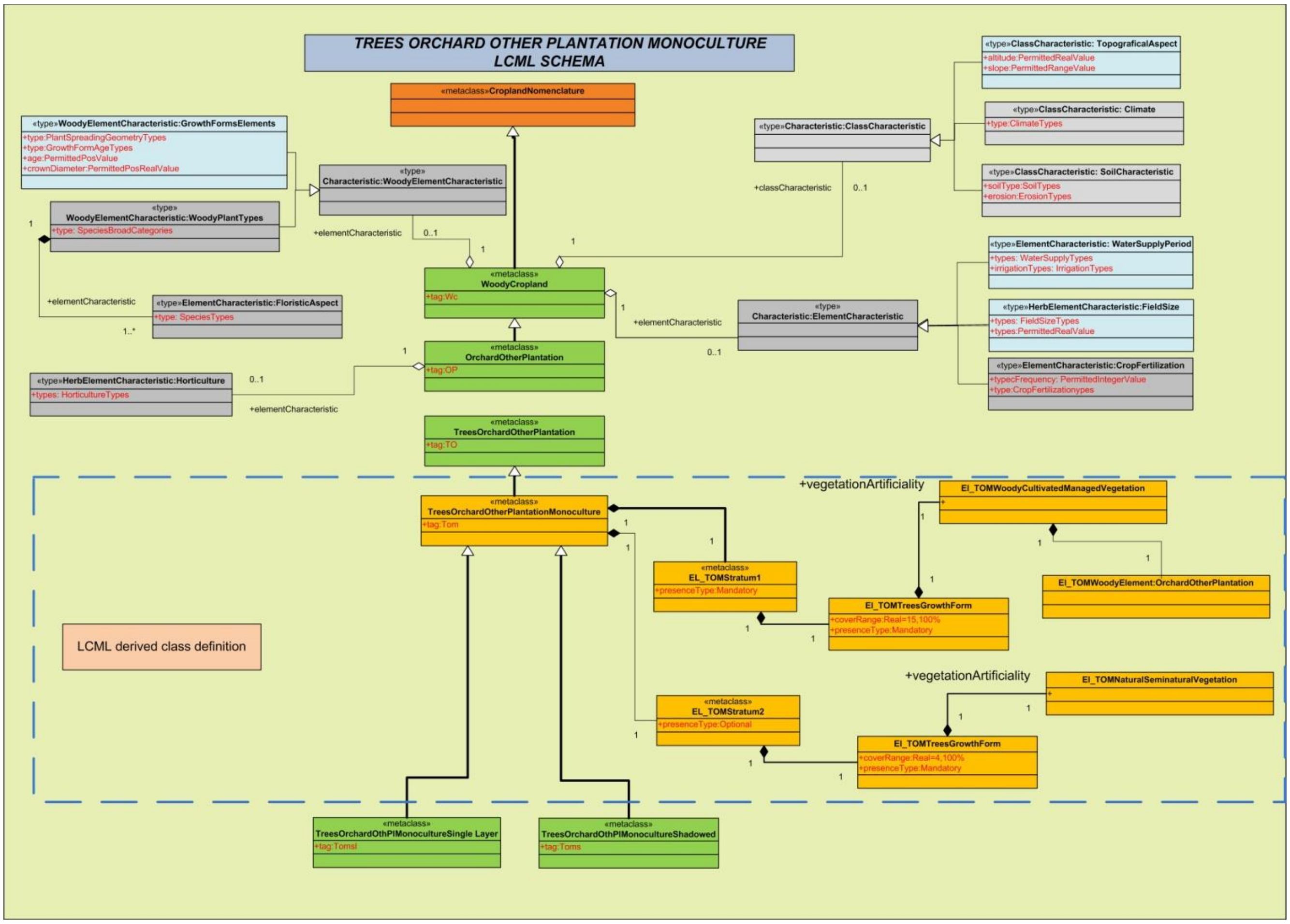


Fig.32 UML schema of the class Trees orchards and other Plantations monoculture

This class defines a Trees orchards and other plantation class were the absence of any further strata of herbaceous crop is clearly indicated. Optionally another strata of natural trees can be present; this situation will further define in the lower nodes *shadowed* and *no shadowed* Trees orchards and other plantations.

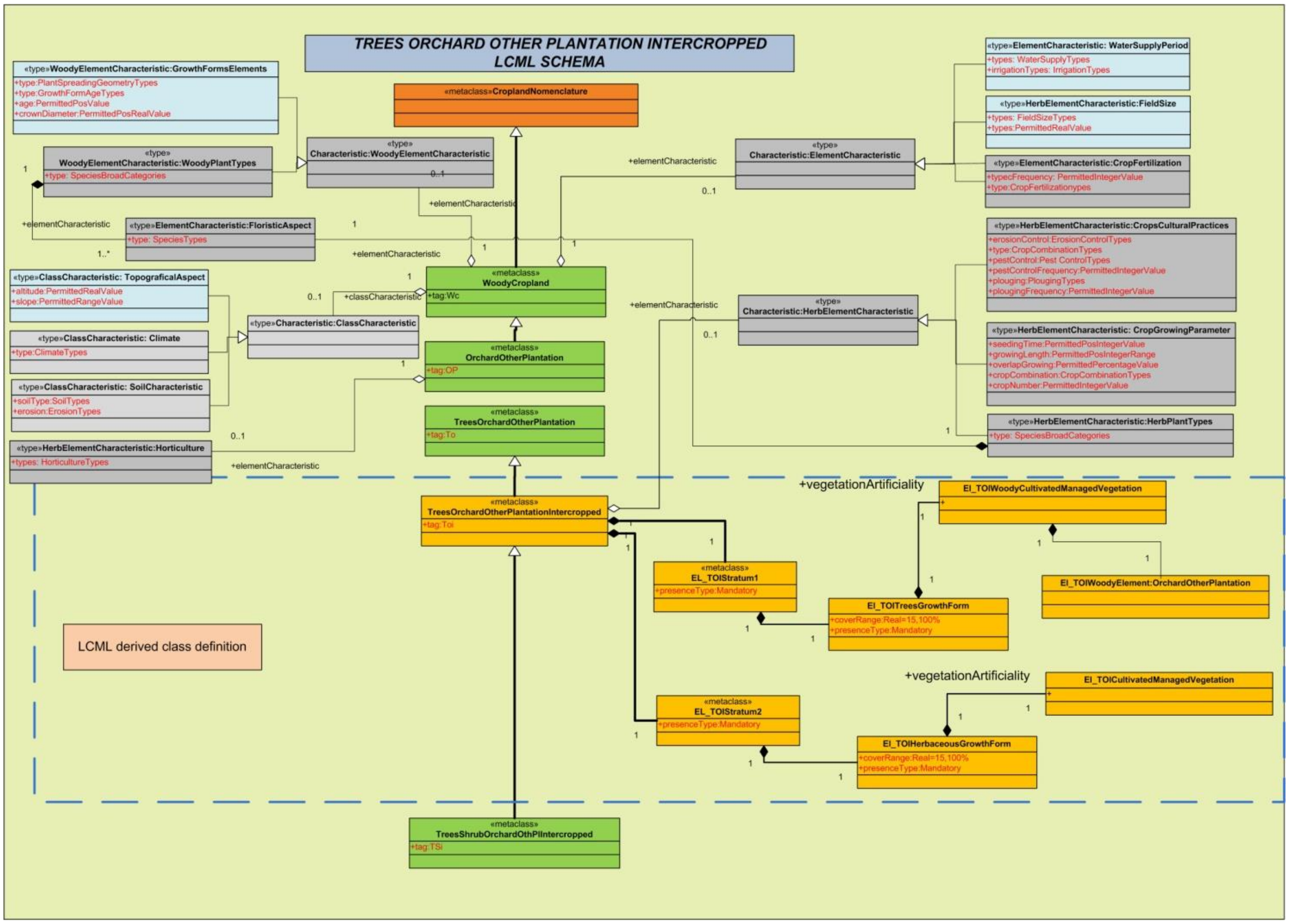


Fig.33 UML schema of the class Tree orchards and other plantations Intercropped

This class defines the conditions to apply for a field situation in which both Trees and Herbaceous crops are present.

Two mandatory main strata are present:

- Trees crop with an attribute of cover set to => 15%
- Herbaceous crop with an attribute of cover set to => 15%

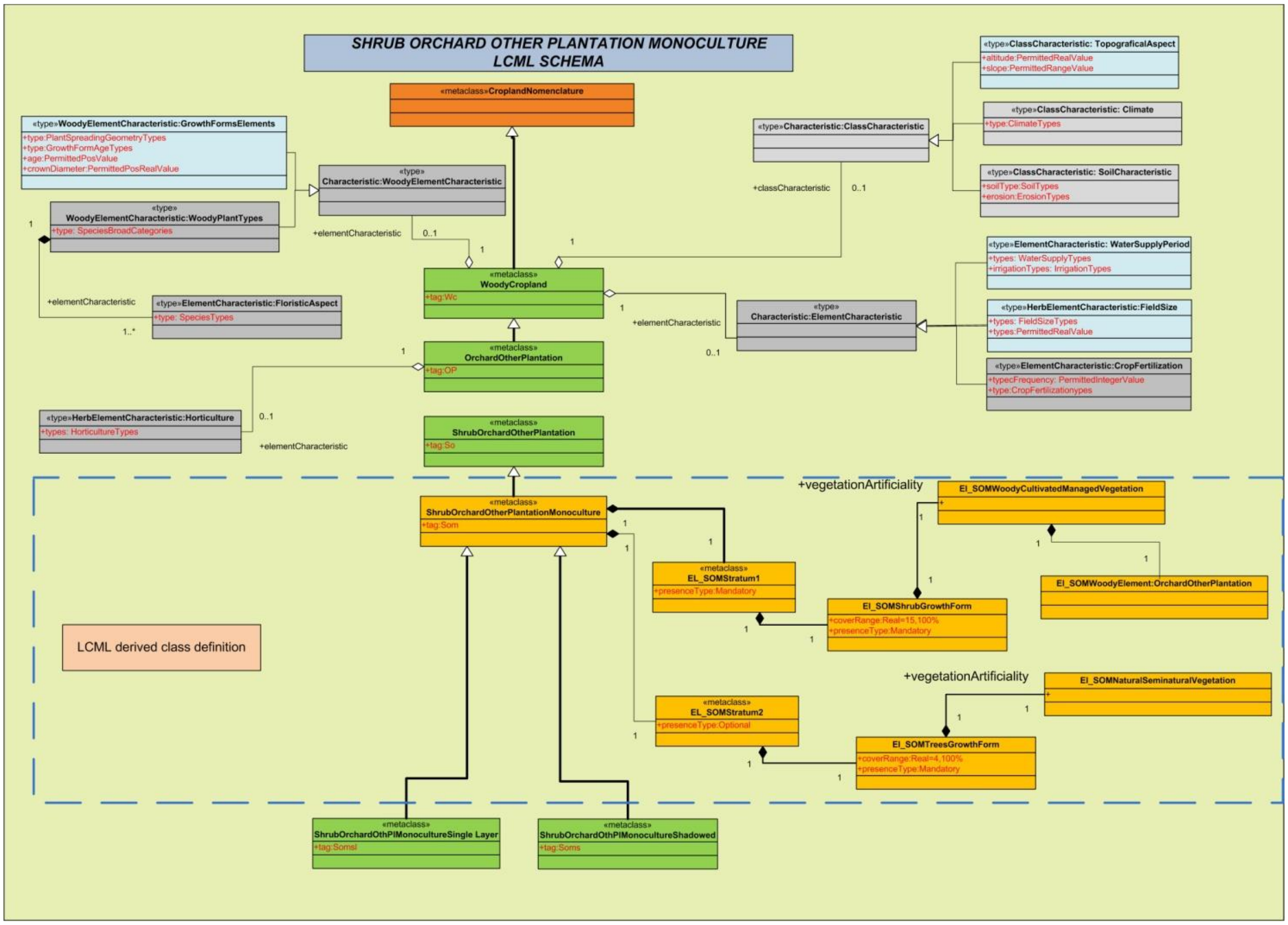


Fig.34 UML schema of the class Shrub orchards and other Plantations Monoculture

This class defines a Shrub orchards and other plantation class were the absence of any further strata of herbaceous crop is clearly indicated. Optionally another strata of natural trees can be present; this situation will further define in the lower nodes *shadowed* and *no shadowed* Trees orchards and other plantations.

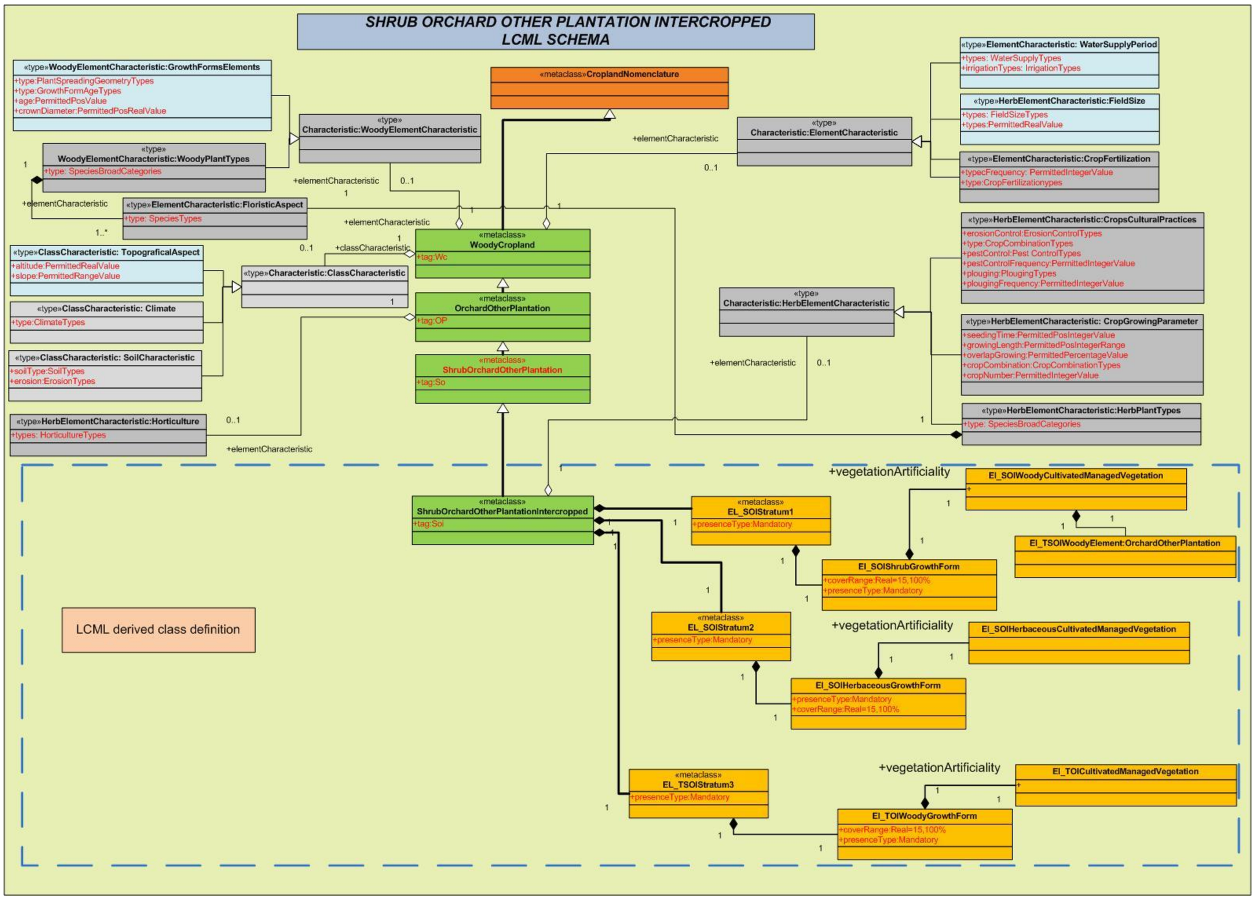


Fig. 35 UML schema of the class Shrub orchards and other Plantations Intercropped

This class defines a field situation in which both Shrub and Herbaceous crops are present. Two mandatory strata are present:

- Shrub crop with a cover attribute set to => 15%
- Herbaceous crop with a cover attribute set to => 15%

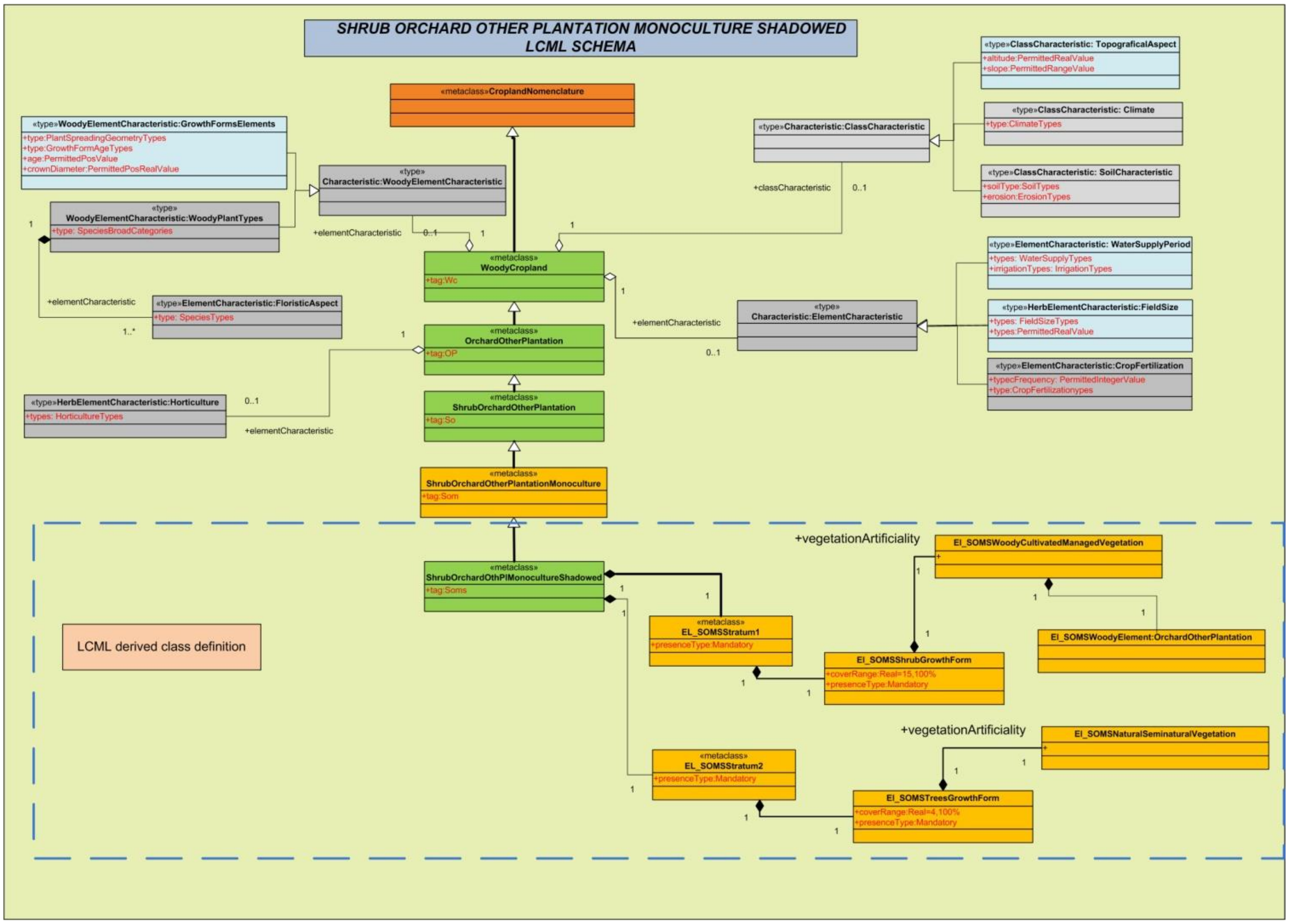


Fig. 36 UML schema of the class Shrub orchards and other Plantations shadowed by natural trees (all conditions set in the above schema).

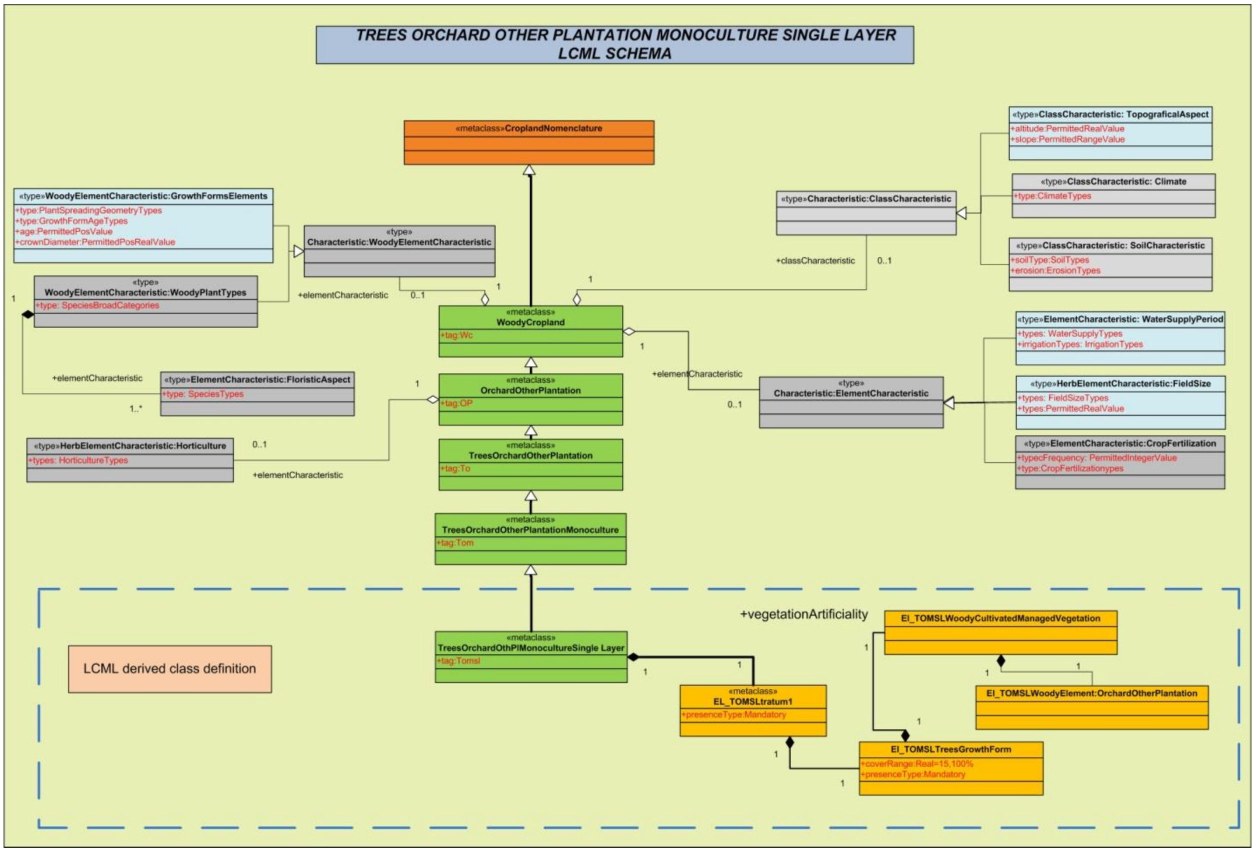


Fig. 37 UML schema of the class Trees orchard and other Plantations monoculture single layer, without any further presence of a natural trees strata.

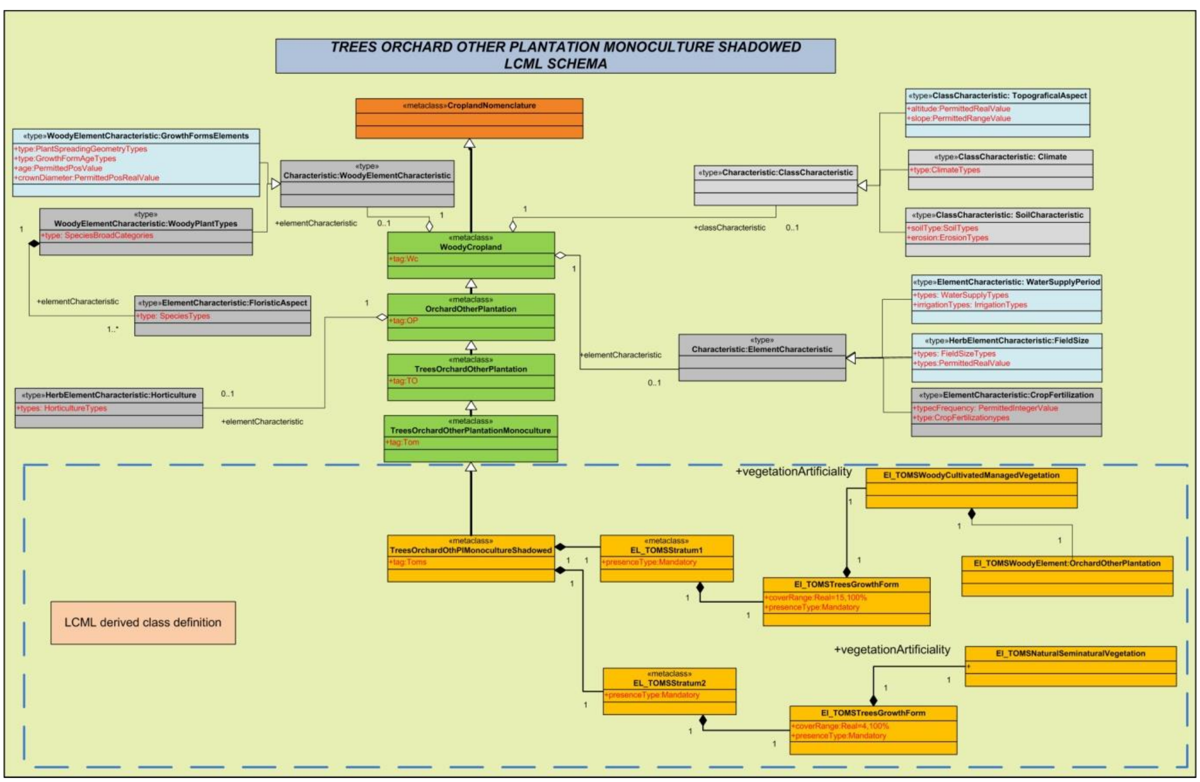


Fig. 38 UML schema of the class Trees orchard and other Plantation Shadowed, with the presence of a natural trees strata.

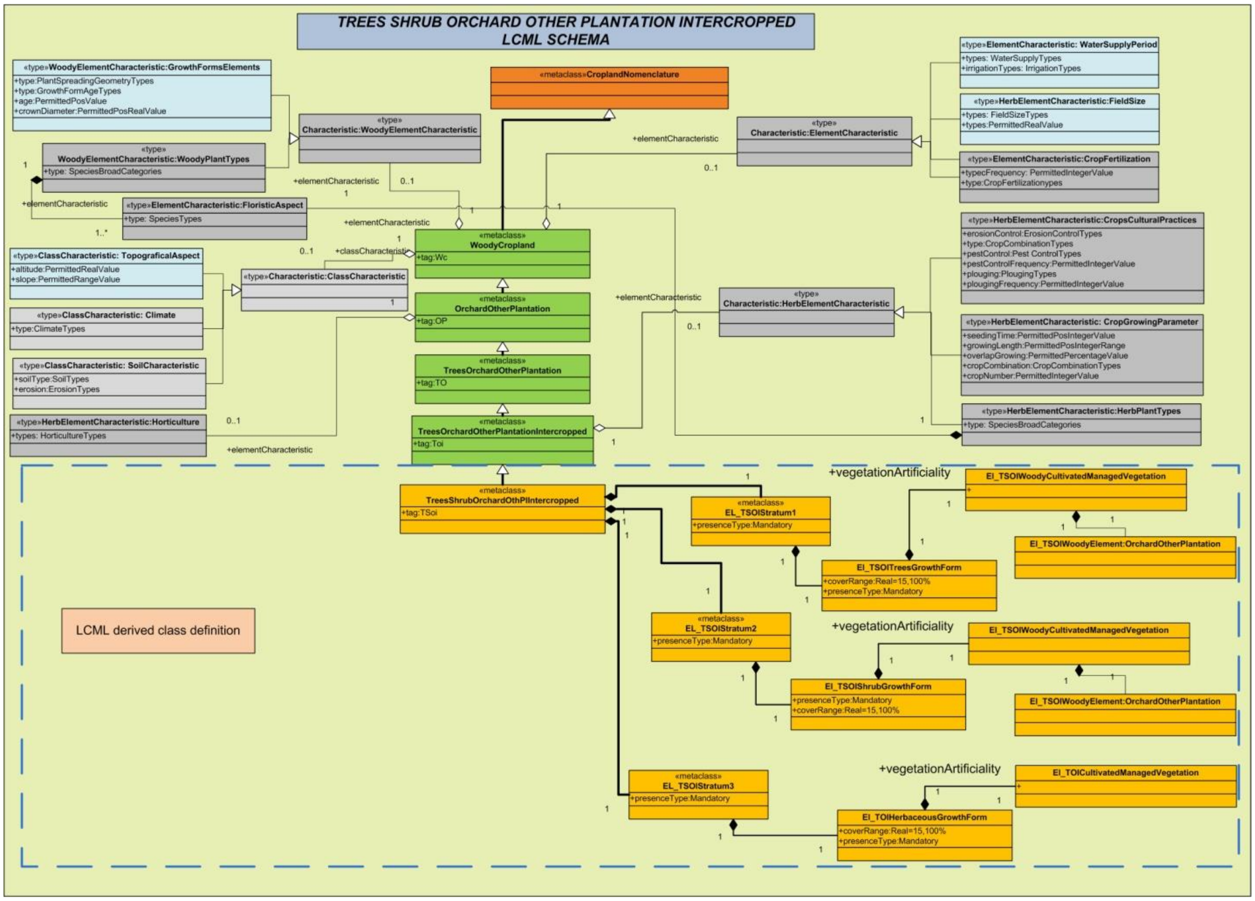


Fig. 39 UML schema of the class Trees Shrub orchards and other Plantation Intercropped

This class defines a field condition (all conditions explained in the schema above) in which three separate strata of crops are present (Tree, Shrub and Herbaceous crops respectively). One typical example of this particular situation are the ancient Oasis in Sahara desert.

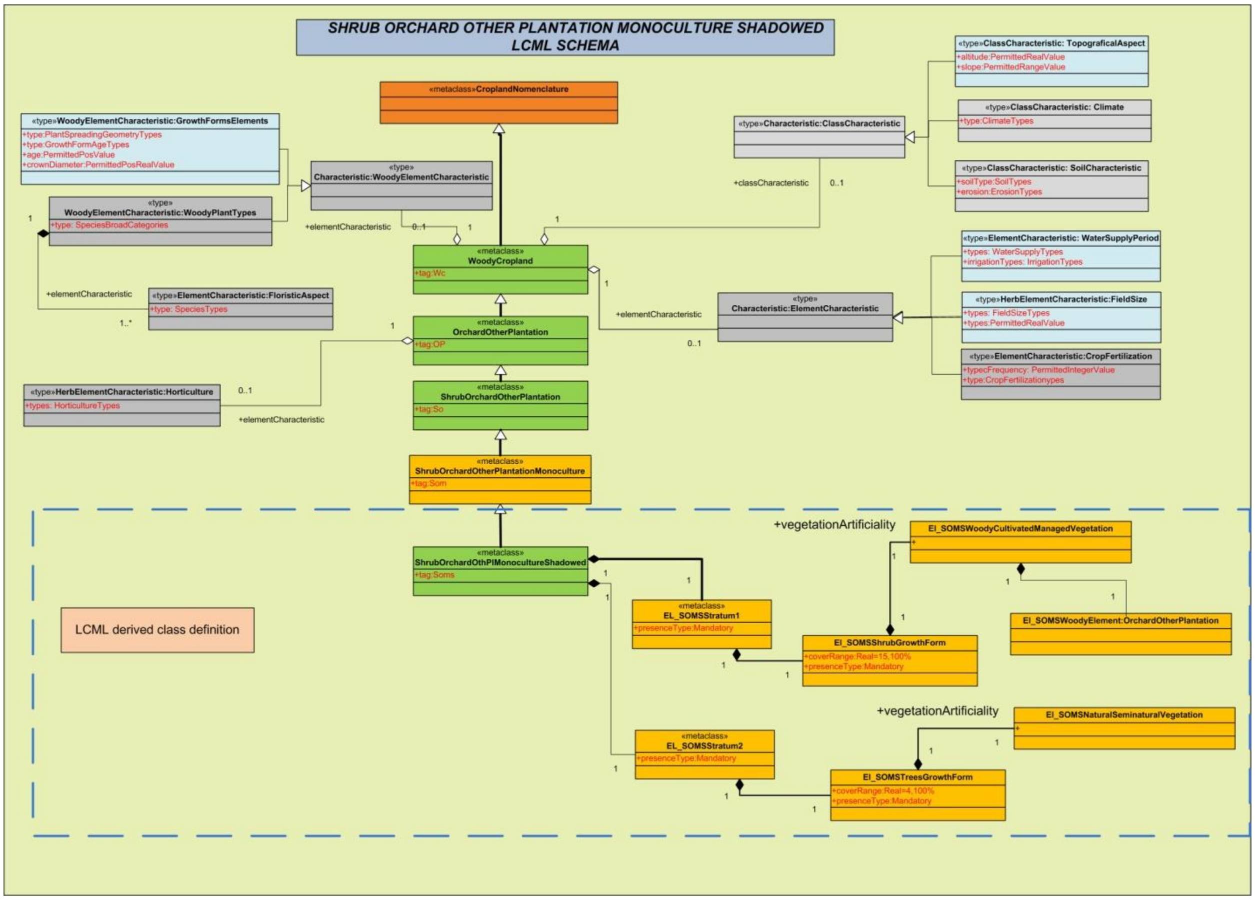


Fig. 40 UML schema of the class Shrub orchard and other plantation monoculture Shadowed by a layer of natural trees (eg. Shadowed coffee or tea plantations in the equatorial area).

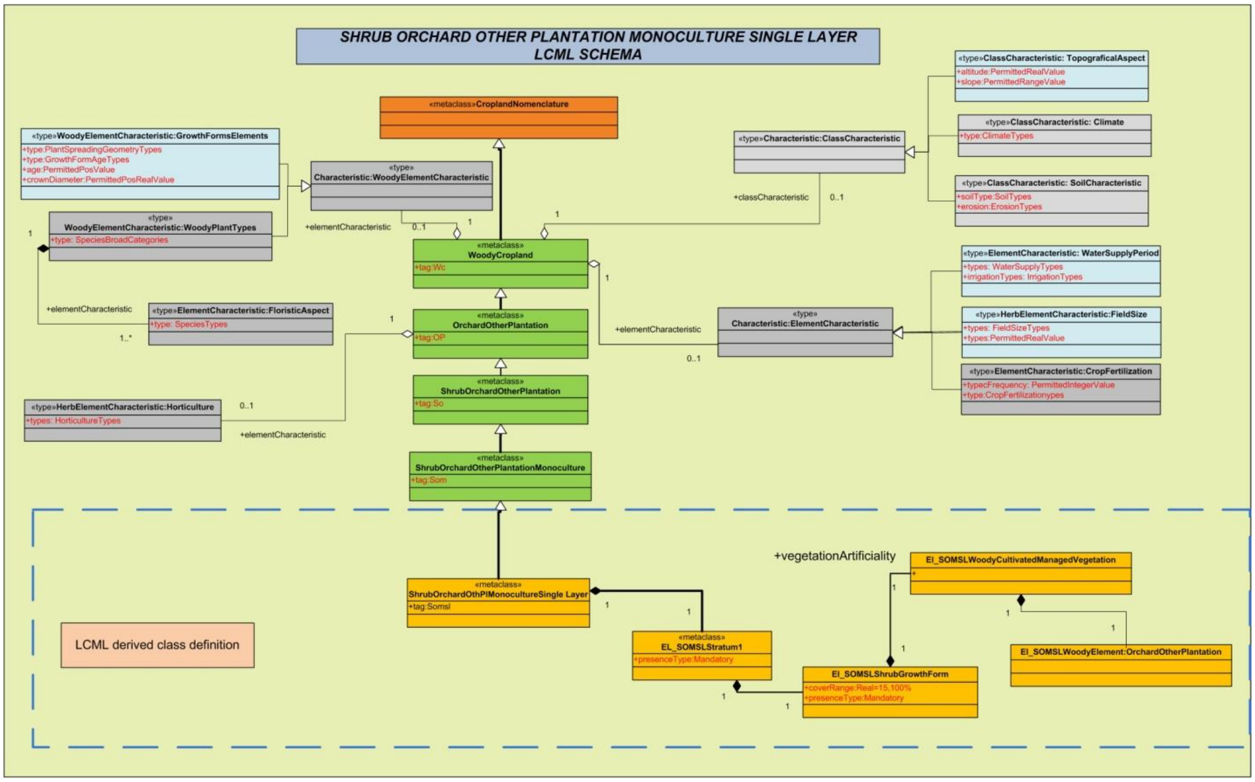


Fig. 41 UML schema of the class Shrub orchard and other plantation Monoculture Single Layer

The fig. 42 shows the box n. 3 that illustrate a relevant part of the classes derived from *Herbaceous cropland* category (mainly *Shifting cultivation* and part of the main class *Permanent Arable Cropland*).
The main category *Shifting cultivation* (fig. 43) further divides in:

- *Shifting cultivation active fields* (fig. 44)
- *Shifting cultivation re-growth* (fig. 45)
- *Shifting cultivation herbaceous re-growth* (fig. 46)
- *Shifting cultivation woody re-growth* (fig.47)

The main category *Permanent Arable cropland* (fig. 48) is represented partly in box 3 (*Wetland cultivation* fig. 49 and *Herbaceous cropland* fig.50) and partly in box 4 (Small *Scale herbaceous cropland).*
The category *Herbaceous cropland* is further divide in:

- *Herbaceous cropland open* (fig. 51)
- *Herbaceous cropland layered* (fig.52)
- *Herbaceous cropland trees layered* (fig.53)
- *Herbaceous cropland shrub layered* (fig.54)

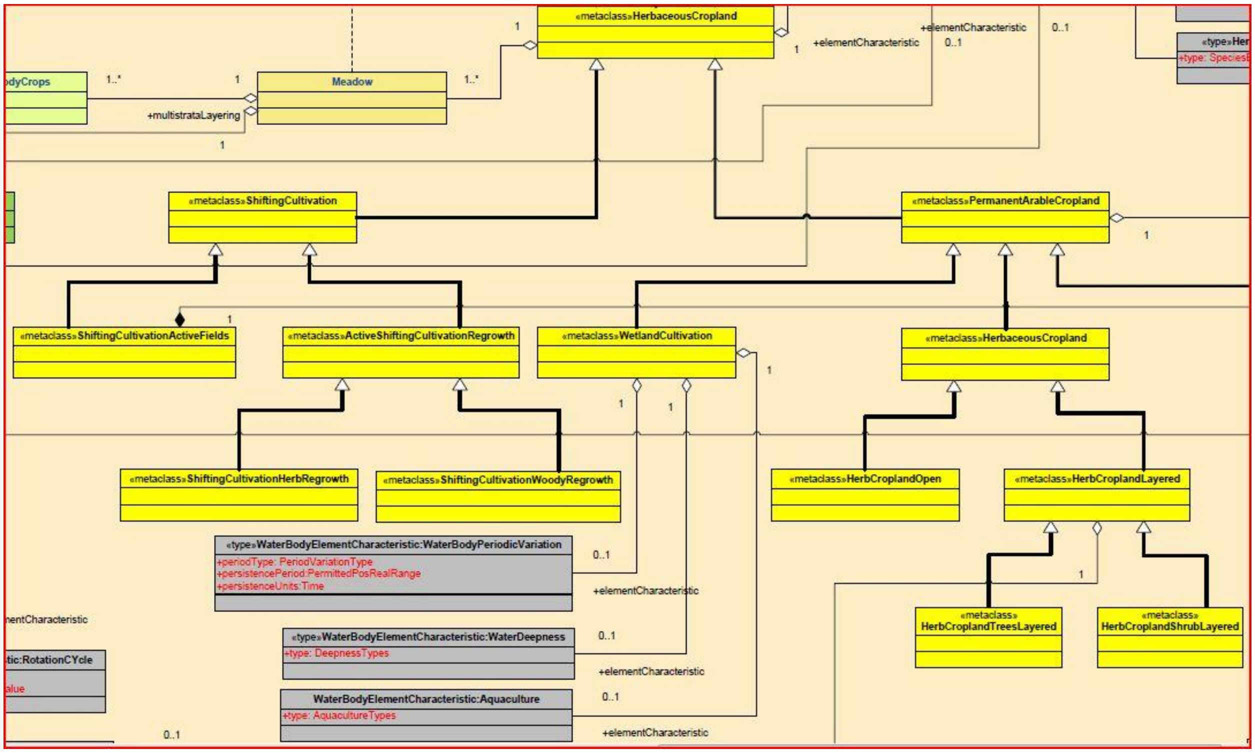


Fig. 42 shows UML portion represented in box 3 (fig. 23)

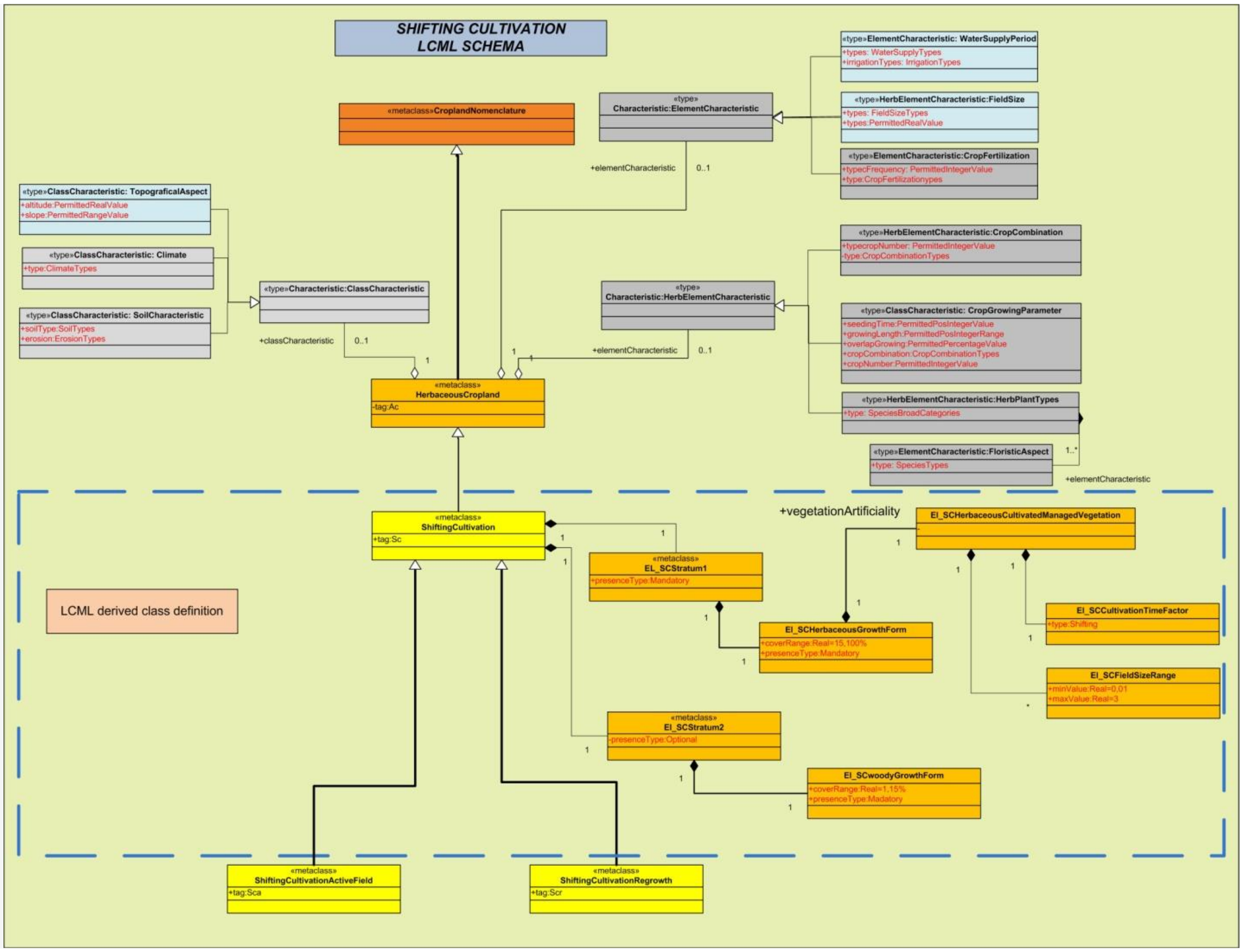


Fig. 43 UML schema of the class Shifting cultivation

This class defines a broad situation of alternating herbaceous cultivation/natural vegetation re- growth occurs. The class conditions are illustrated by a main mandatory strata of Herbaceous crop which cultivation period is set to *shifting* (see glossary) another strata of woody natural vegetation can be present but its cover is not more than 15%.

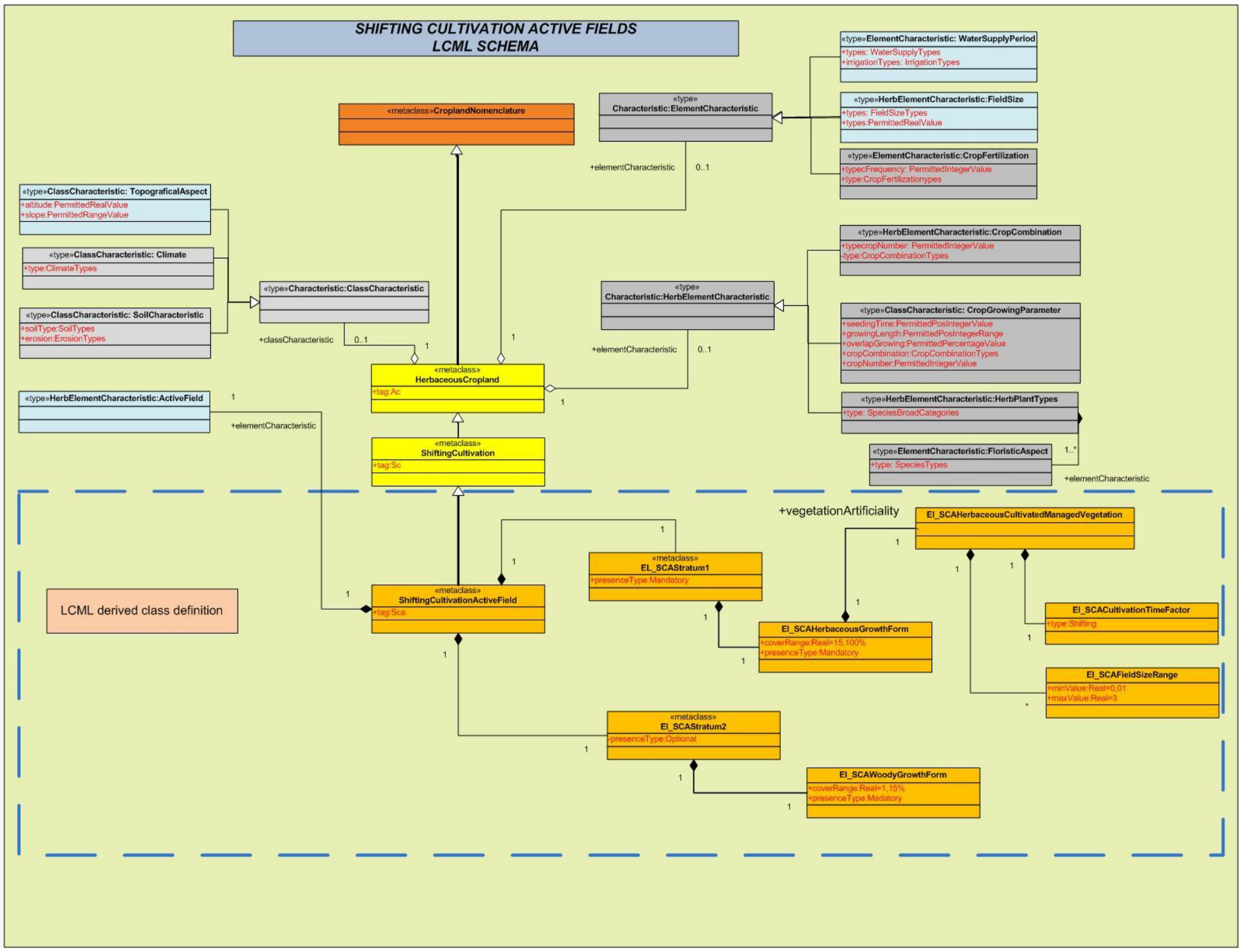


Fig. 45 UML of the class Shifting cultivation active fields.

This class inherit the same rules and conditions of the higher schema node (Shifting cultivation) in addition it require the presence of an effectively cultivated herbaceous crop in the year of the observation (see definition of *Active fields* characteristic in the glossary).

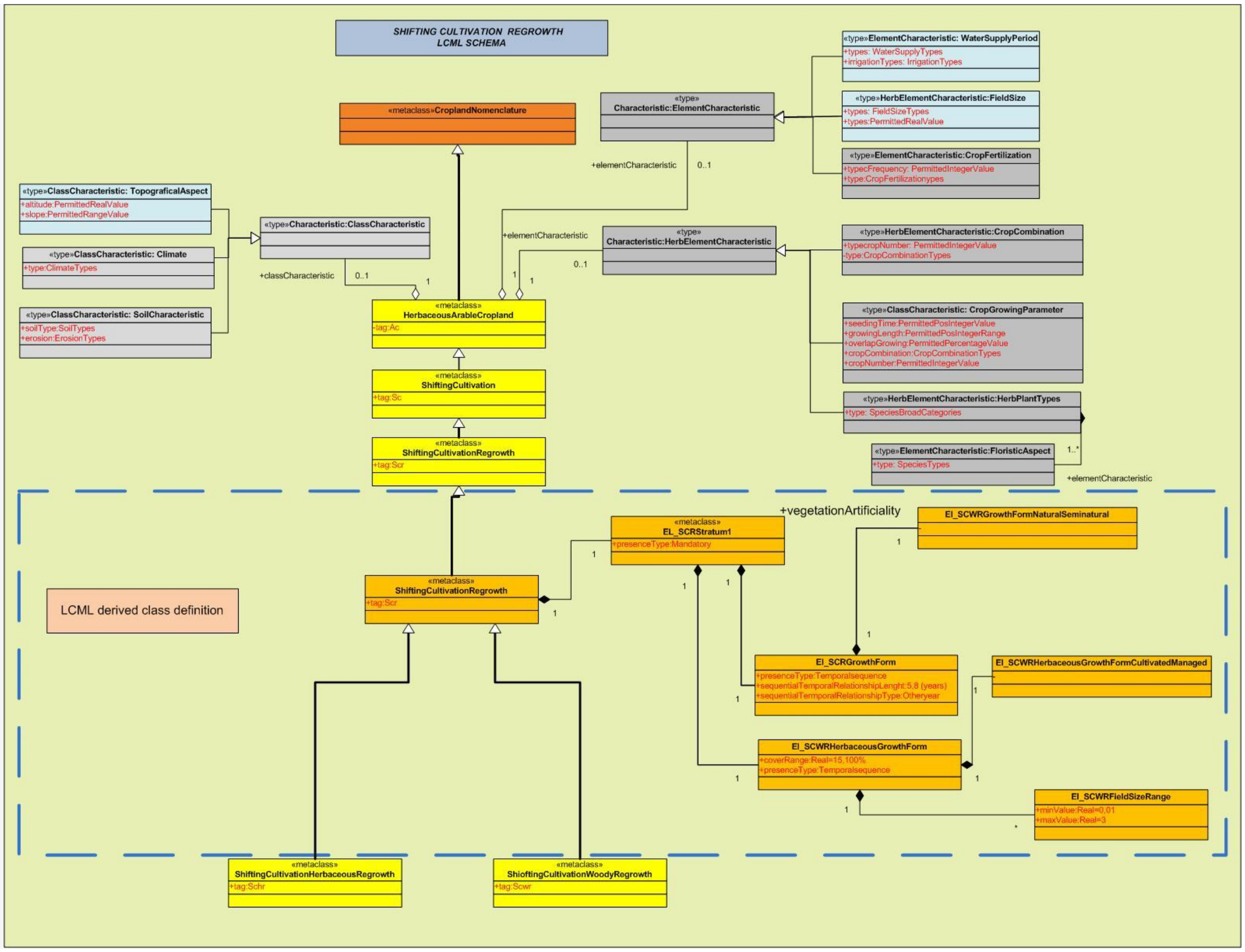


Fig. 45 UML of the class Shifting cultivation re-growth

This class describes a natural re-growth of natural vegetation after a shifting cultivation cycle. The re-growth of natural vegetation before or after an herbaceous crop (that in the present schema is shown in strata 2) is described in the UML schema by the following LCML attributes:

- Presence type set to *temporal sequence*
- *Sequential temporal relationship* set to a range of 5-8 years
- *Sequential temporal relationship type* set to *other year* meaning that this temporal relationship is not between the growing seasons of a current year but between different years

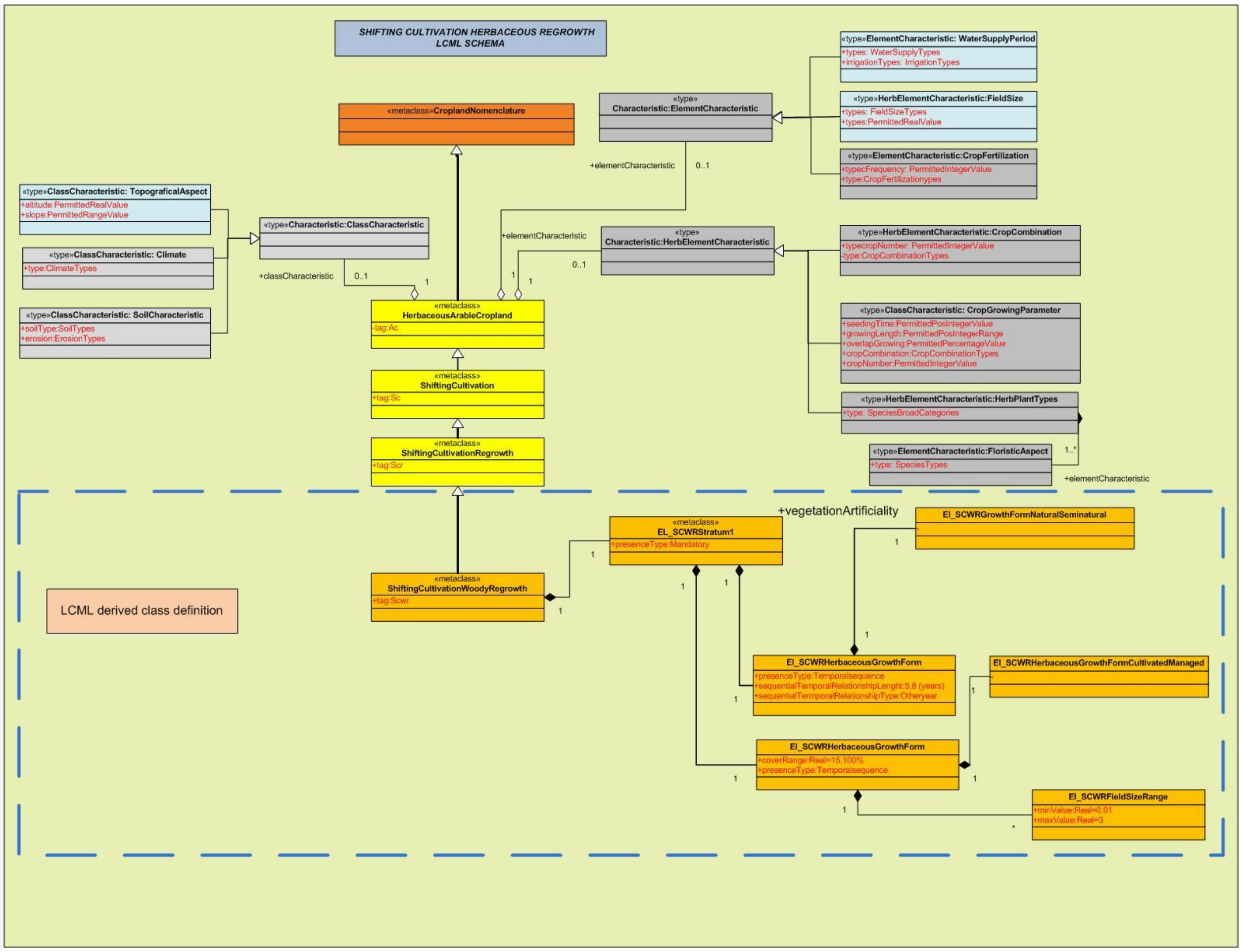


Fig. 46 UML of the class Shifting cultivation herbaceous re-growth; this class use the same conditions of the higher node (Shifting cultivation re-growth) the only difference is that the type of re-growth is detailed as *Herbaceous*.

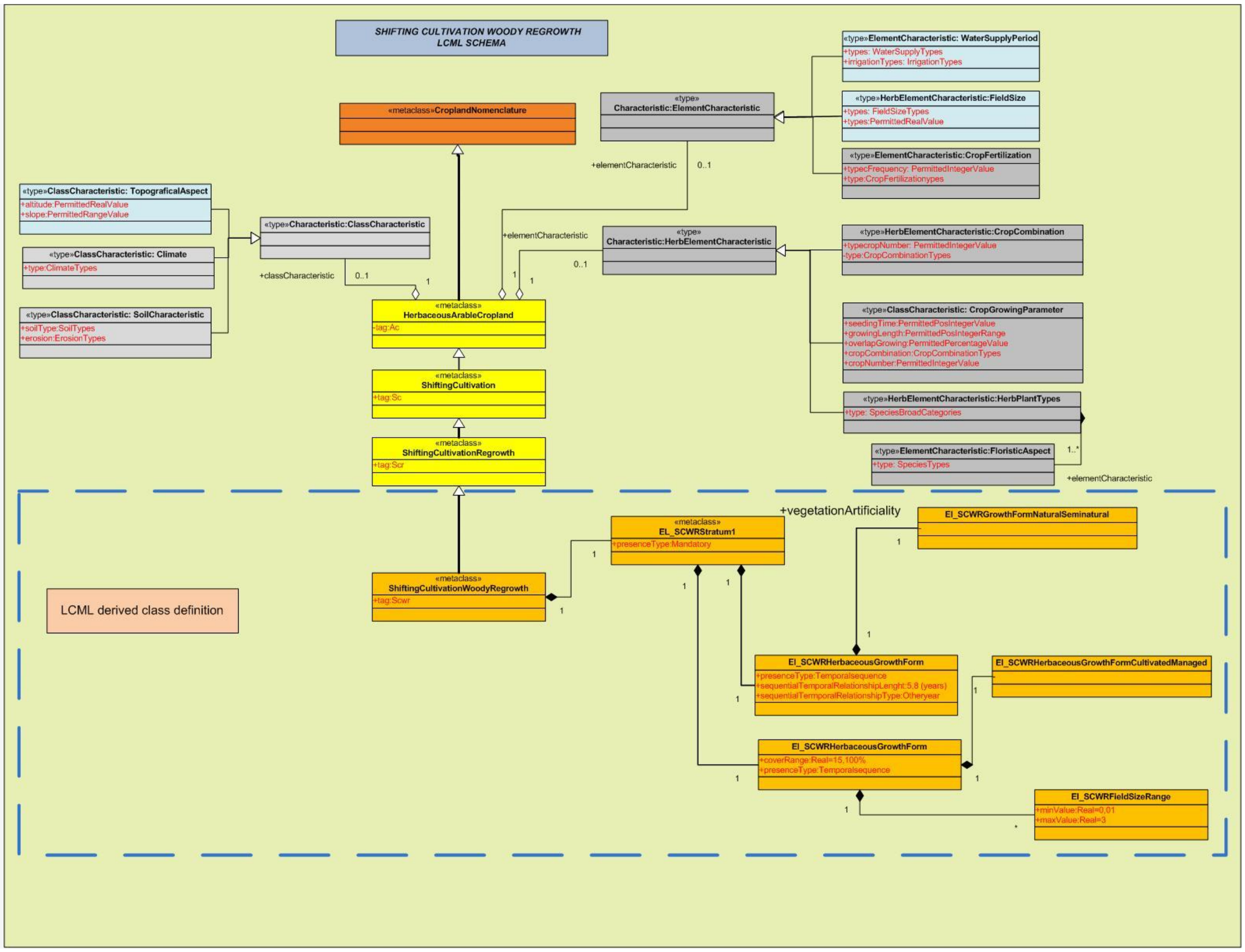


Fig. 47 UML of the class Shifting cultivation woody re-growth; this class use the same conditions of the higher node, only the re-growth is specified as *Woody*.

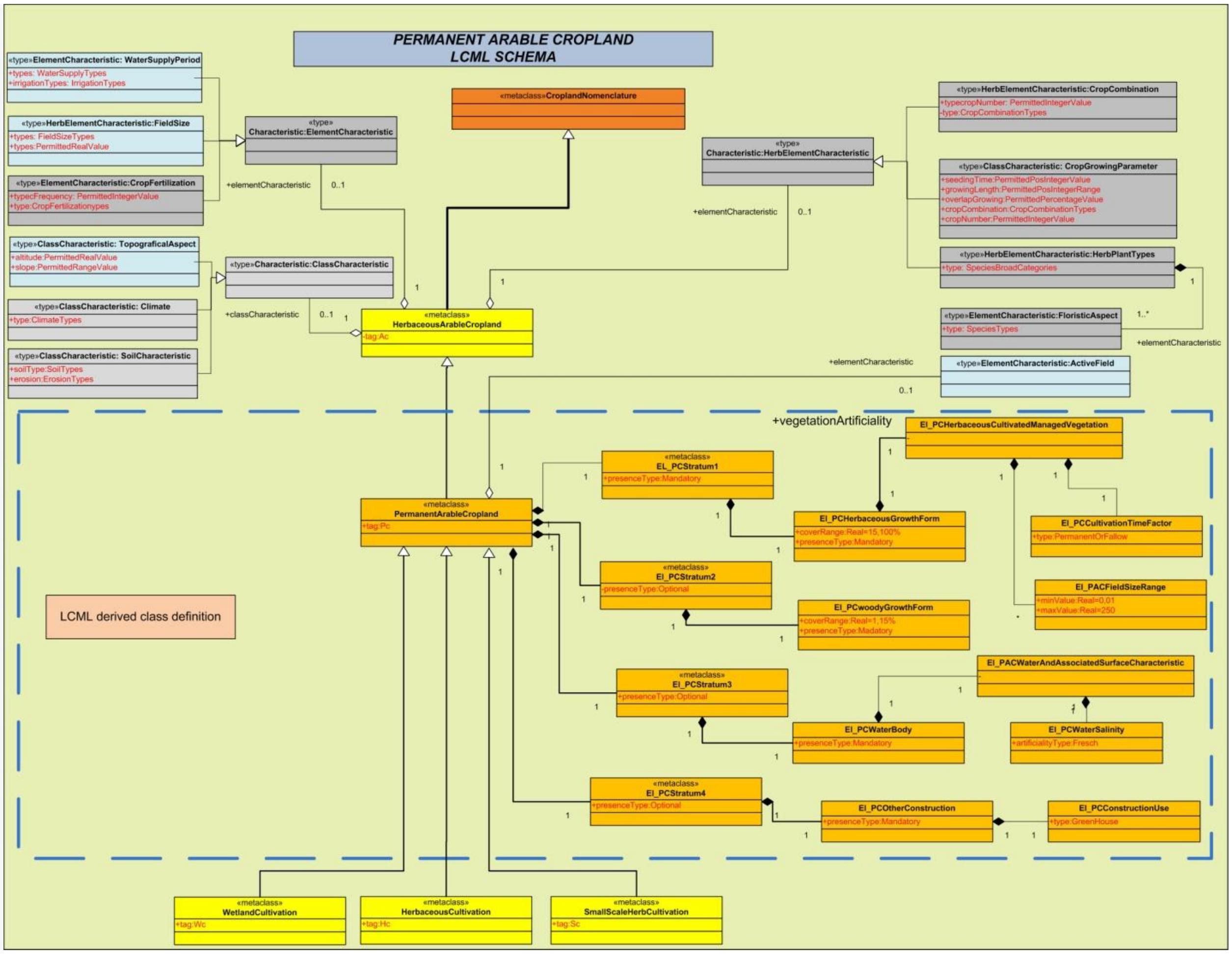


Fig. 48 UML of the class Permanent Arable cropland

This class defines a wide range of field conditions (excluding Shifting cultivation) including wetland cultivation, terrestrial fallow and permanent herbaceous crops and confined horticulture. At this level of generalization many optional strata are present; these strata will gradually disappear (or make explicit) depending from the specific characteristics of the cultivations to be represented.

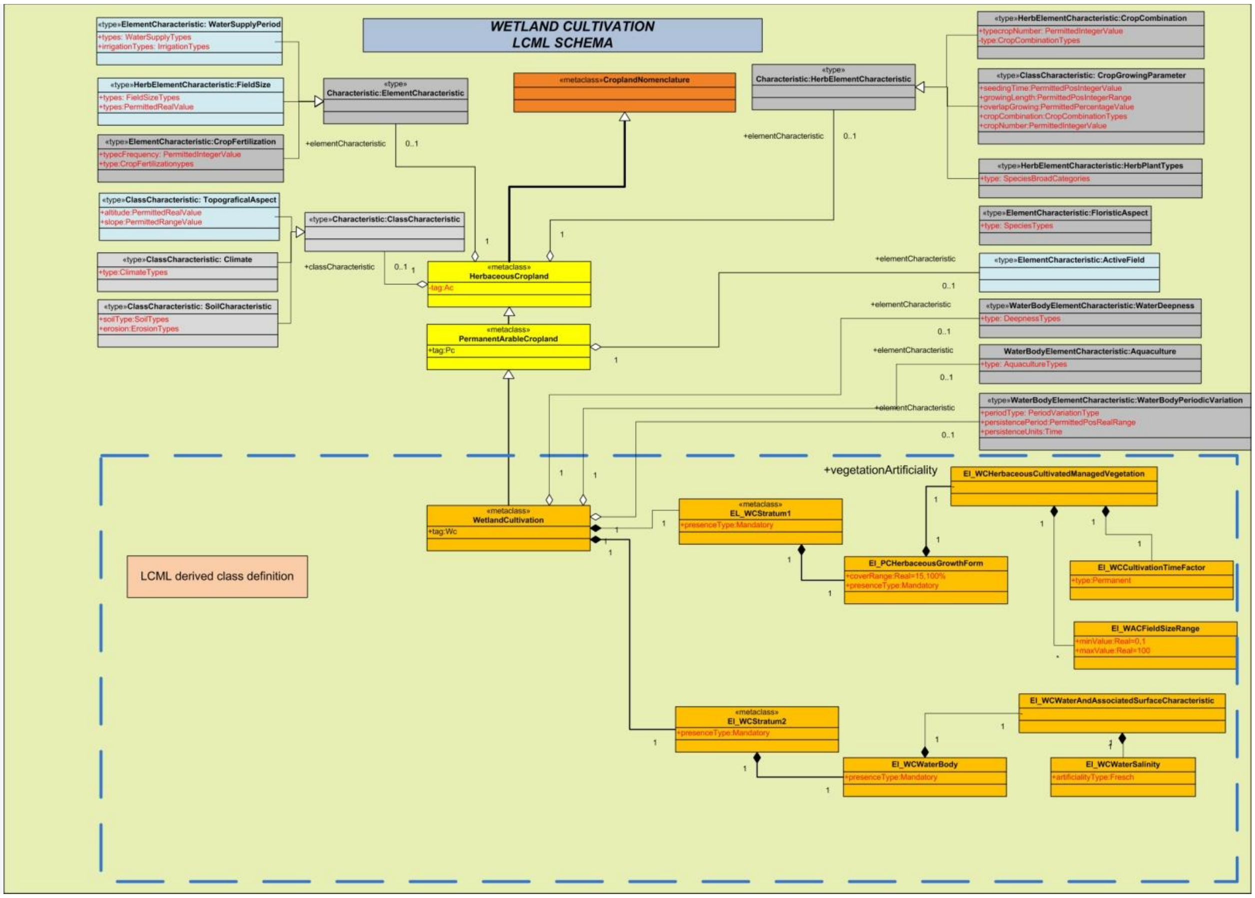


Fig. 49 UML of the class Wetland cultivation.

This class defines a typical wetland cultivation (paddy rice etc.). Two mandatory strata must be present:

- Herbaceous crop (attributes and characteristics shown above in the schema)
- Fresh water present during all the cultivation period

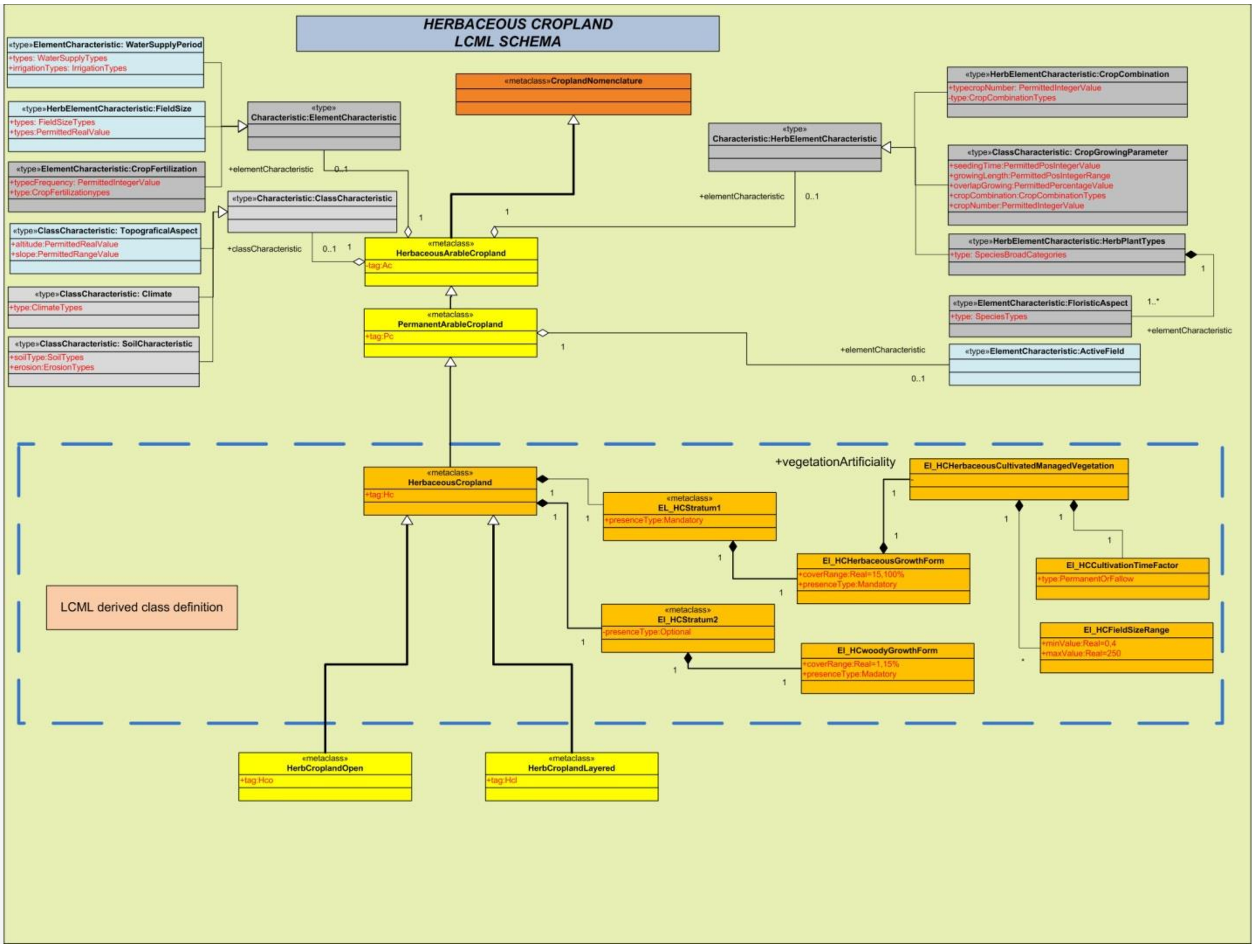


Fig. 50 UML of the class Herbaceous cropland defined as:

- Herbaceous crop mandatory strata (attributes and characteristics defined in the UML schema)
- Woody natural vegetation optional strata

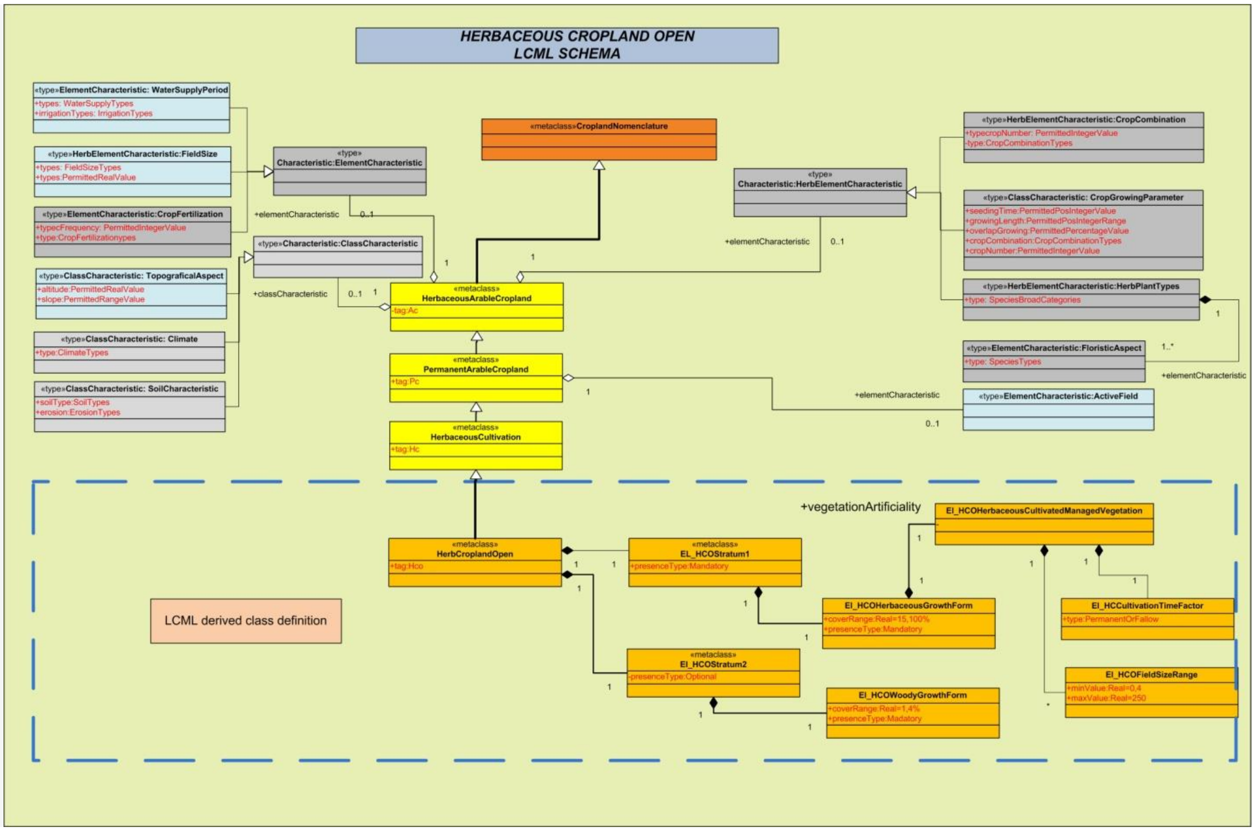


Fig. 51 UML of the class Herbaceous cropland open, defines a herbaceous field crop without (or negligible presence > 4% cover) the presence of a woody natural vegetation strata.

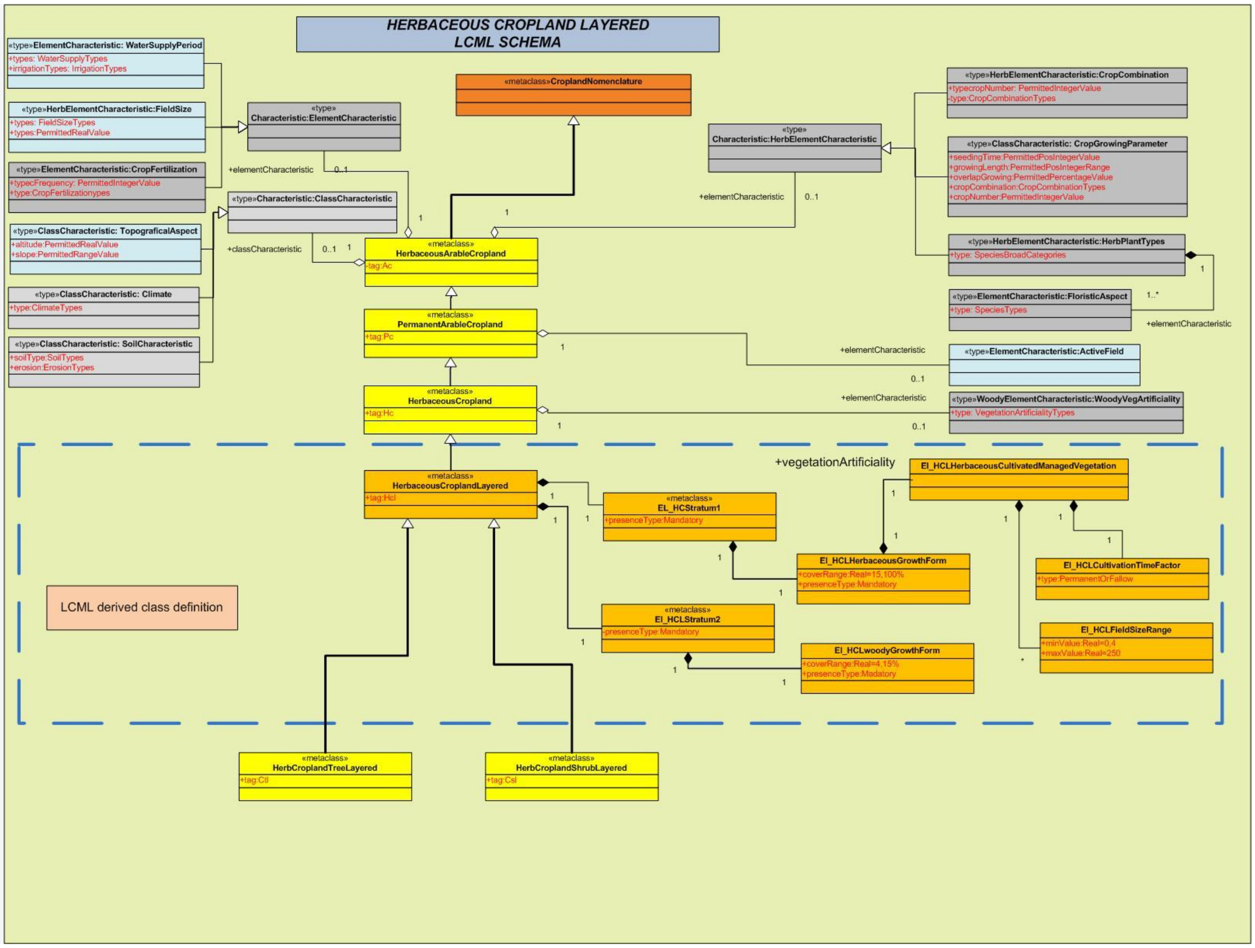


Fig. 52 UML of the class Herbaceous cropland layered, describe an herbaceous crop field with a certain presence (always > than 15% cover) of woody natural vegetation.

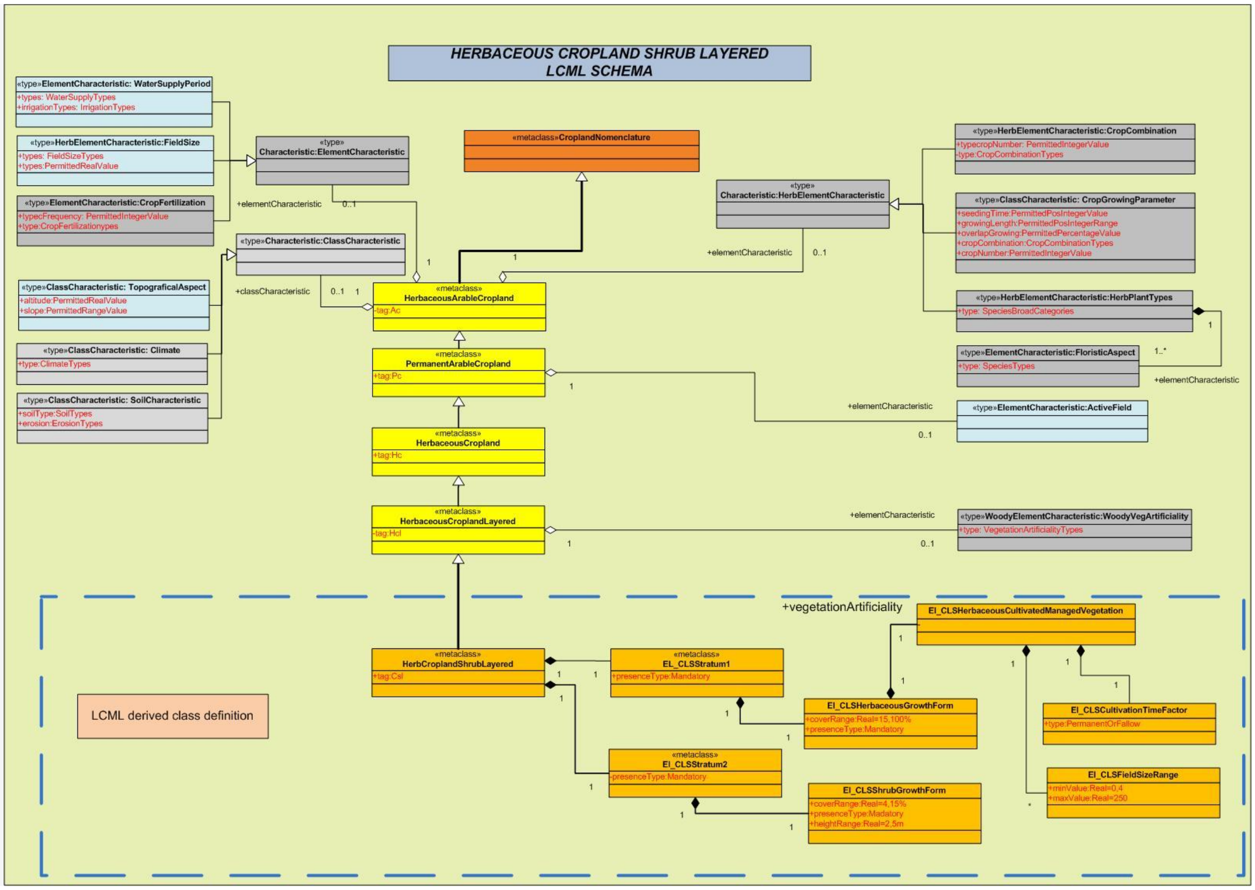


Fig. 53 UML of the class Herbaceous cropland shrub layered

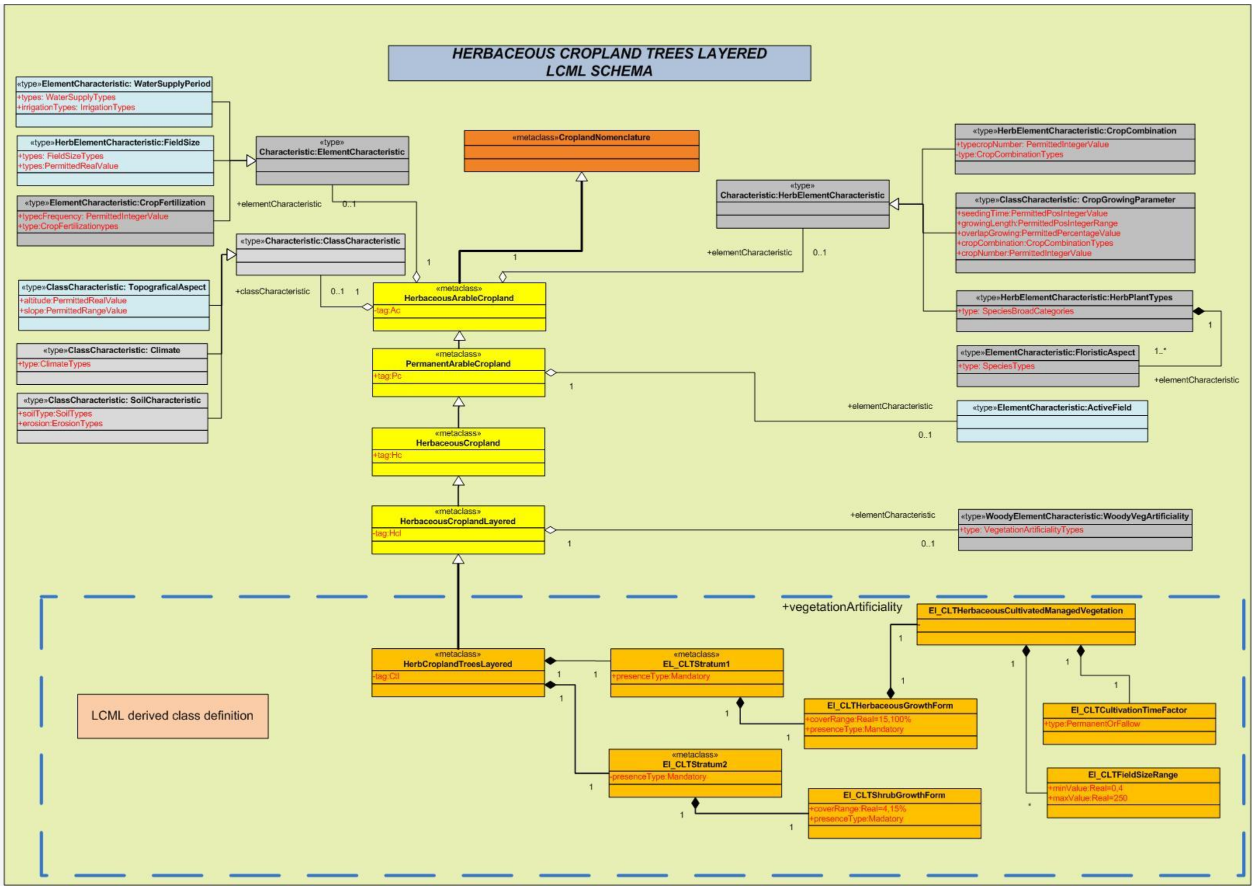


Fig. 54 UML of the class Herbaceous cropland trees layered.

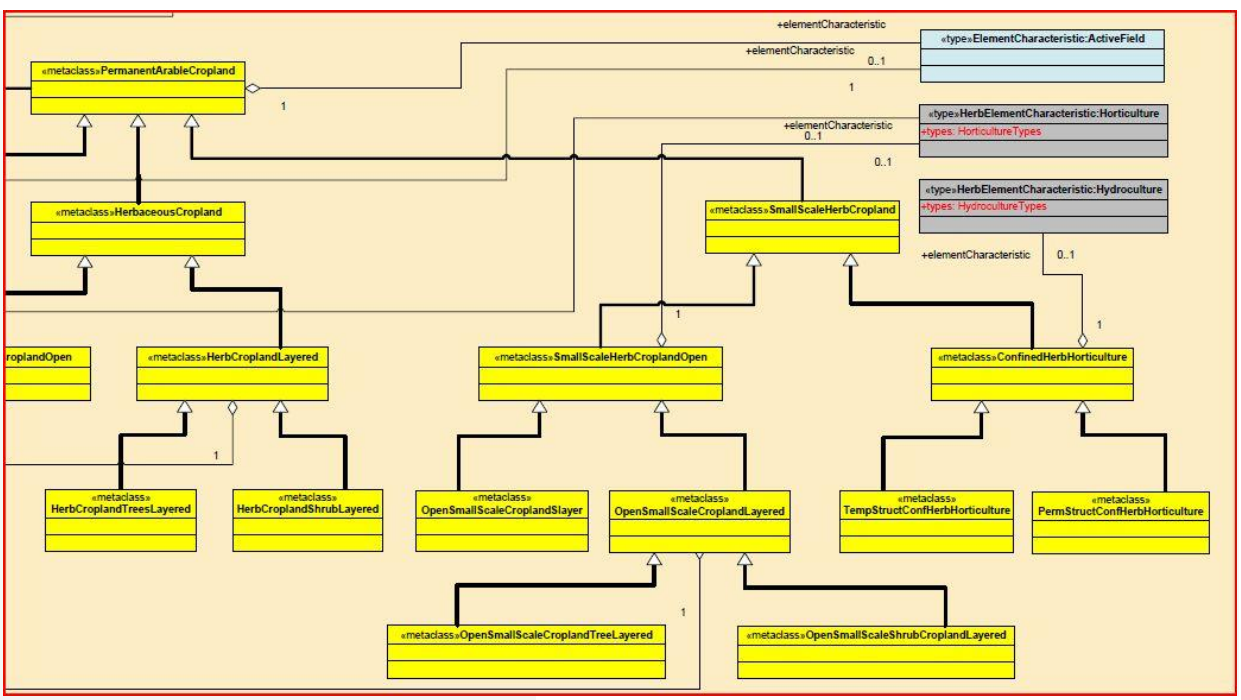


Fig.55 shows UML enlarged box 4.

In box 4 (fig. 55) the last part of the UML categories are shown. The main class is *Small scale herbaceous cropland* (fig.56) that further divides in:

- *Small scale herbaceous cropland open* (fig. 57)
- *Confined herbaceous horticulture* (fig.58)

Further sub-division of these two categories is:

- *Open small scale cropland single layer* (fig. 59)
- *Open small scale cropland layered* (fig. 60)
- *Open small scale cropland tree layered* (fig. 61)
- *Open small scale cropland shrub layered* (fig. 62)

- *Temporary structure confined herbaceous horticulture* (fig. 63)
- *Permanent structure confined herbaceous horticulture* (fig. 64)

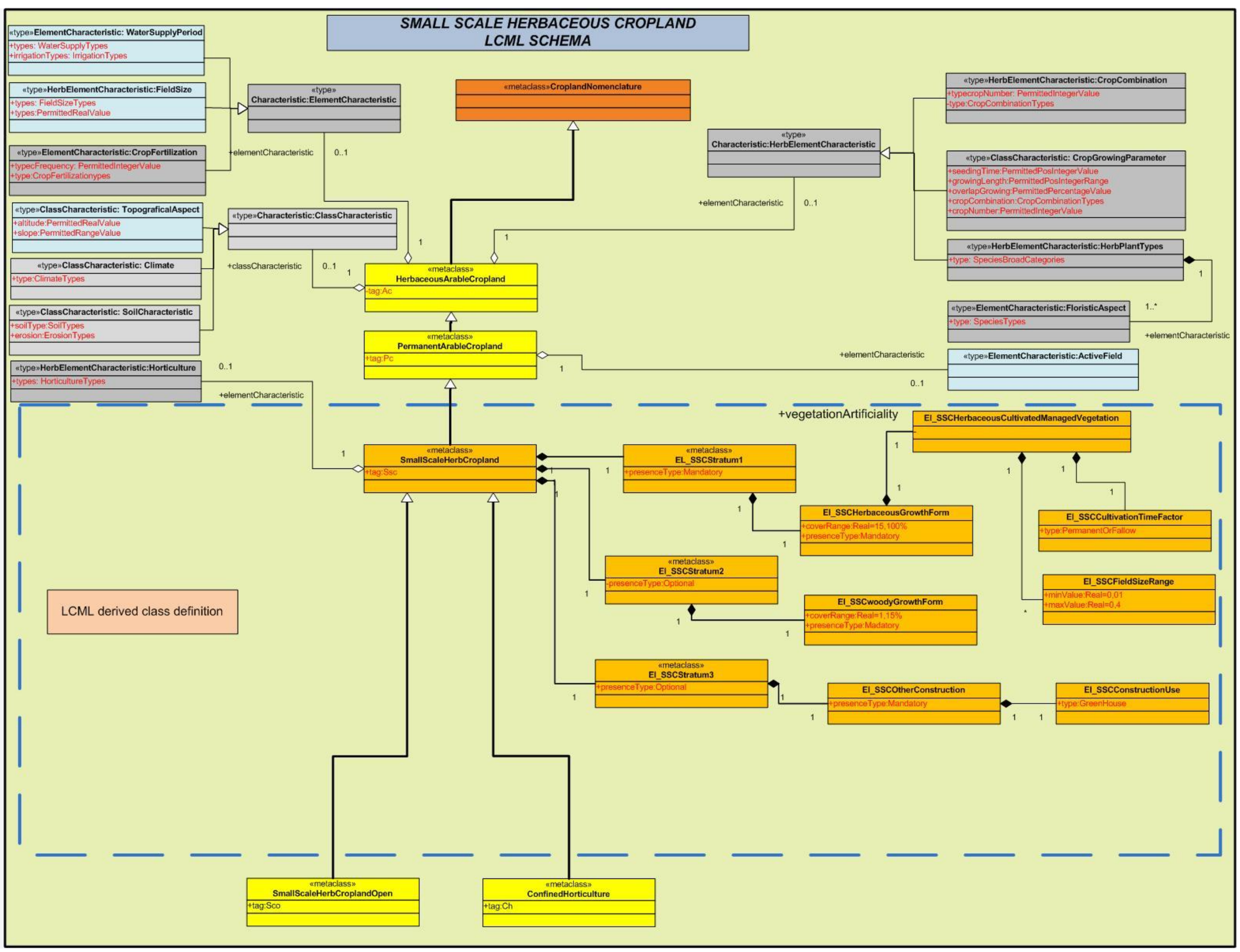


Fig. 56 UML of the class *Small scale herbaceous cropland*

This class defines Herbaceous field crops very similar to the class Herbaceous cropland (fig. 50), the critical differentiation is the *Field size* characteristic that in this case is set to < than 0,4 Ha. This constraint is set in the UML schema to represent very small scale cultivations including horticulture gardens (confined in green houses or not).

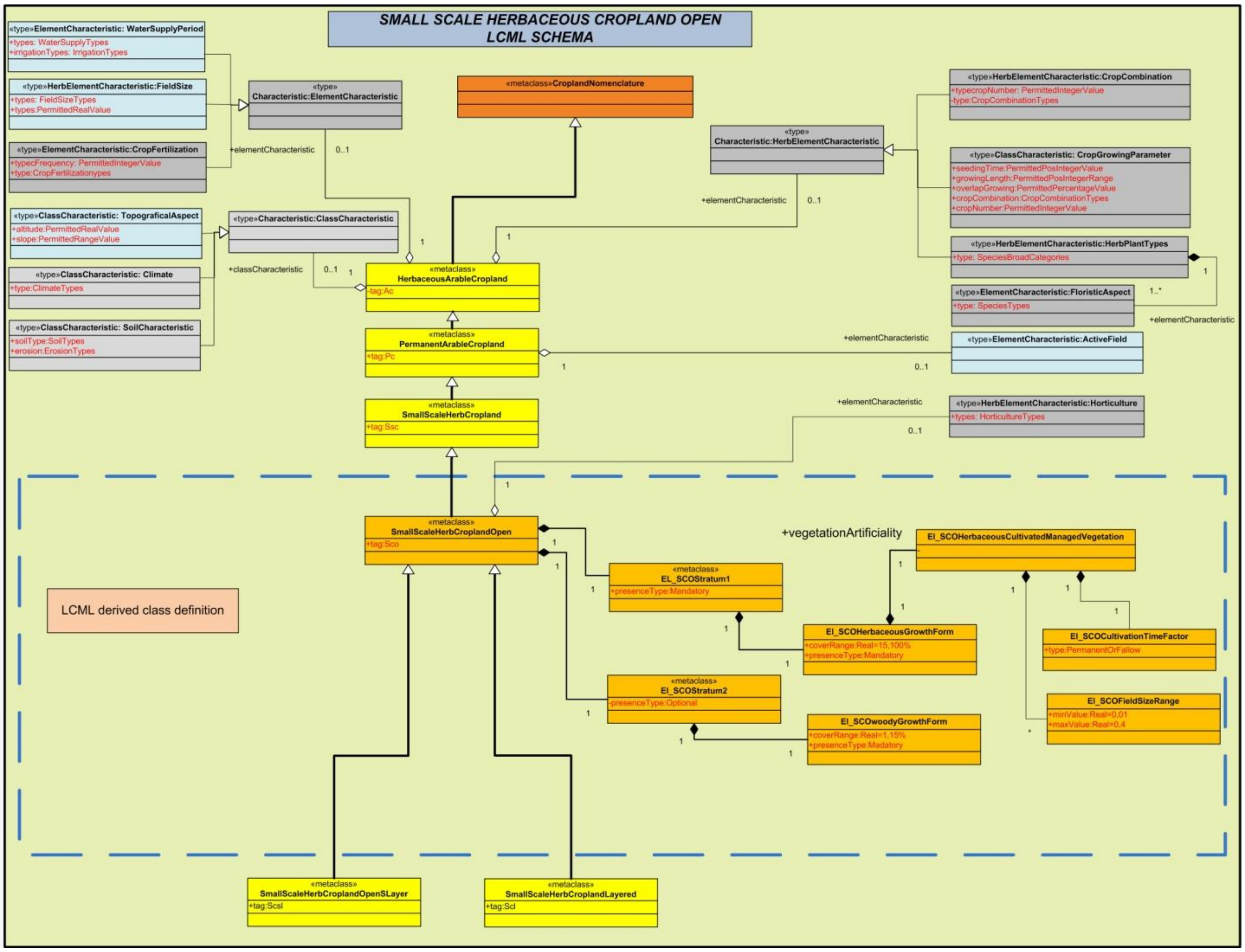


Fig. 57 UMl of the class *Small scale herbaceous cropland open* defines cultivations not confined in temporary or permanent structures (all the conditions are shown in the above schema).

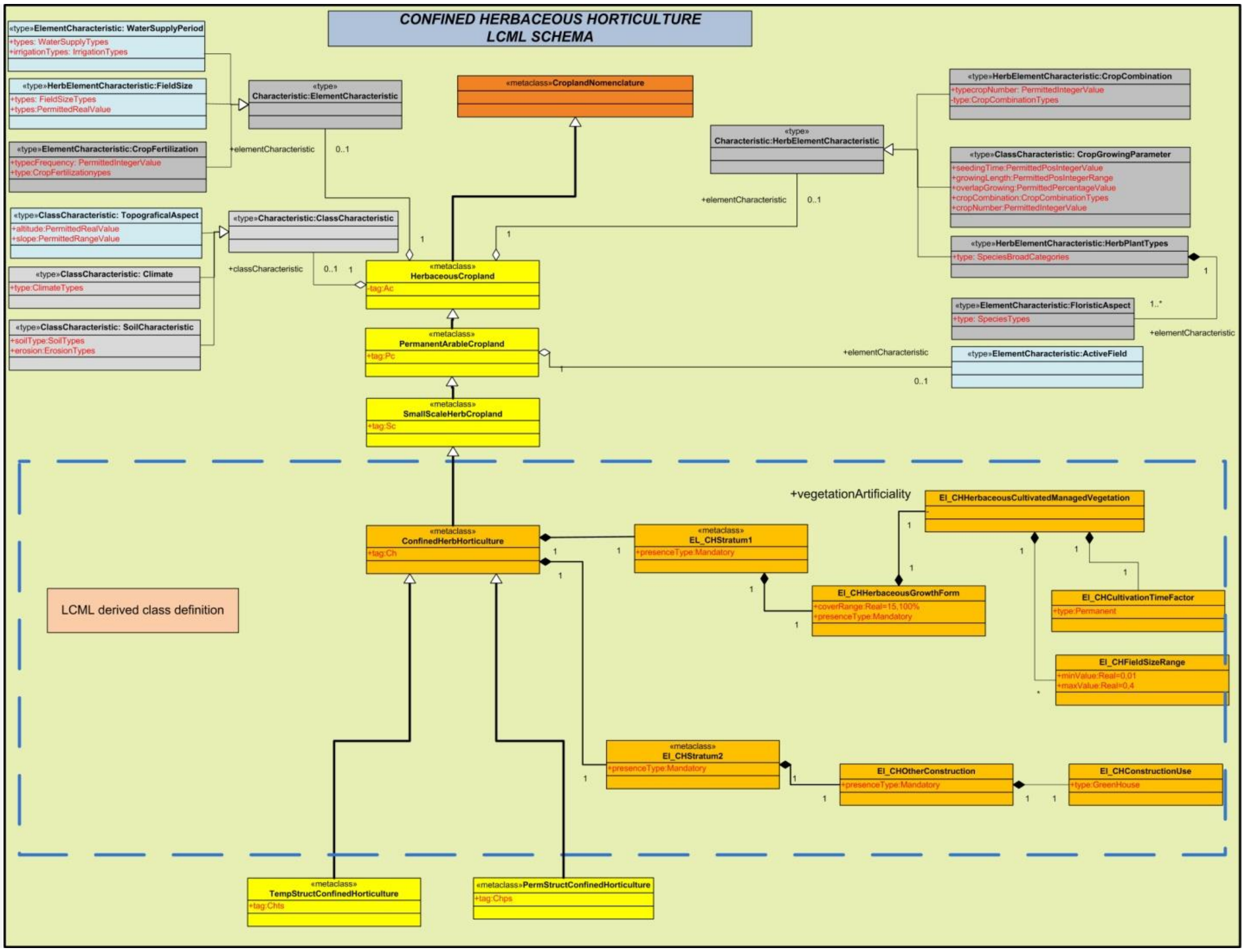


Fig. 58 UML of the class *Confined herbaceous horticulture* defines all the confined horticulture gardens confined in temporary or permanent structures.

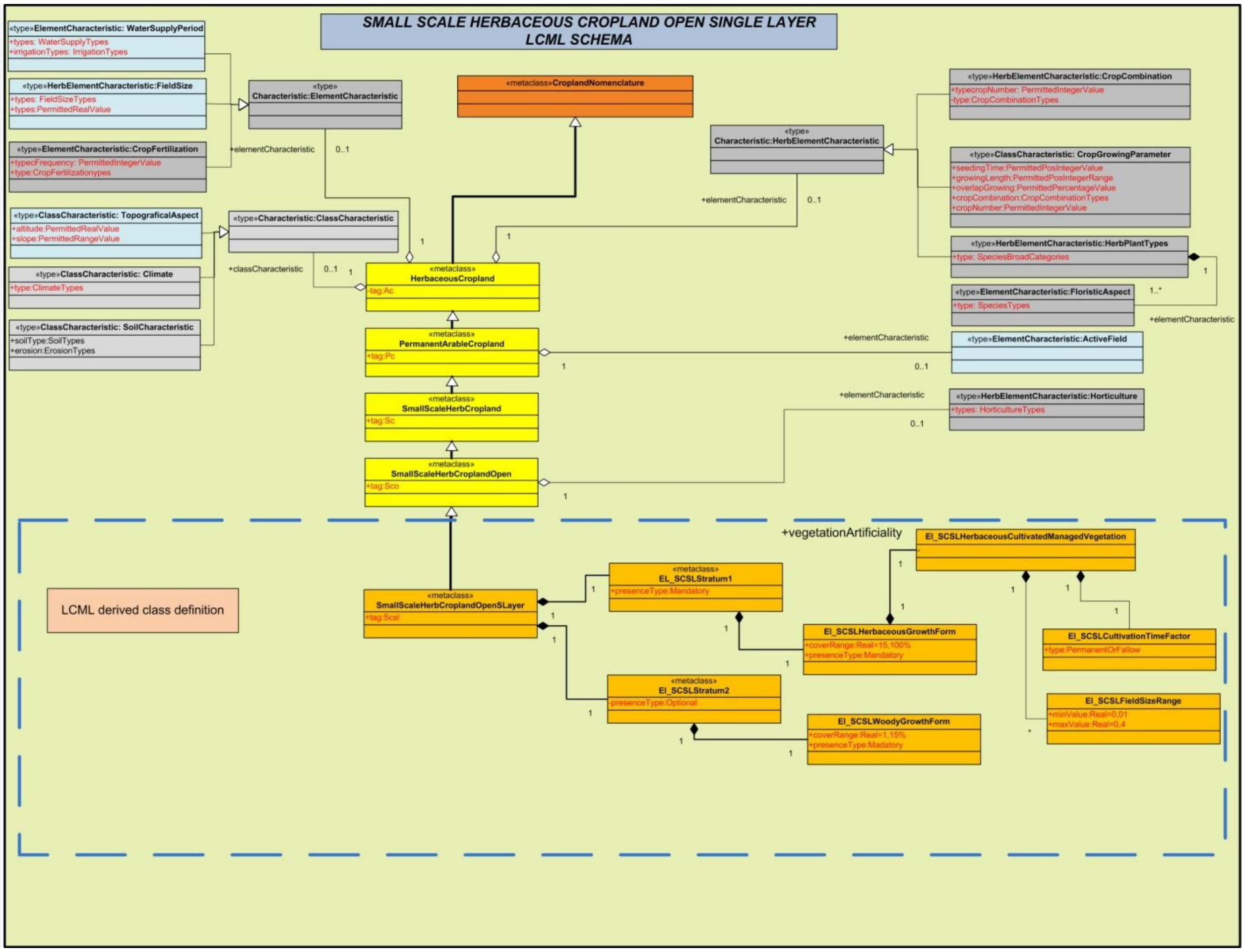


Fig. 59 UML of the class *Small scale herbaceous cropland open single layer* (with no substantial presence of woody natural vegetation).

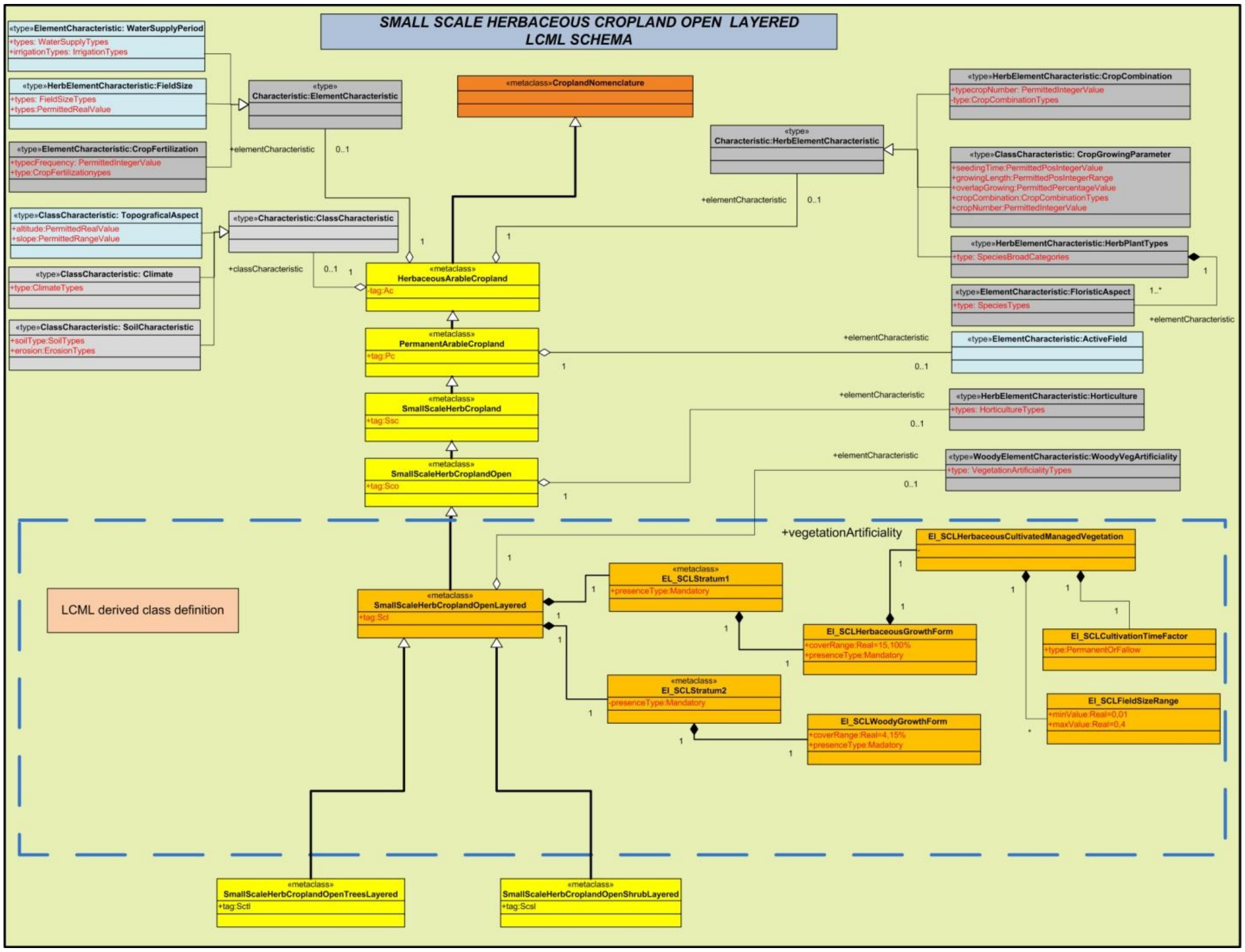


Fig.60 UML of the class *Small scale herbaceous cropland open layered* with a certain presence (always < than 15% cover) of woody natural vegetation.

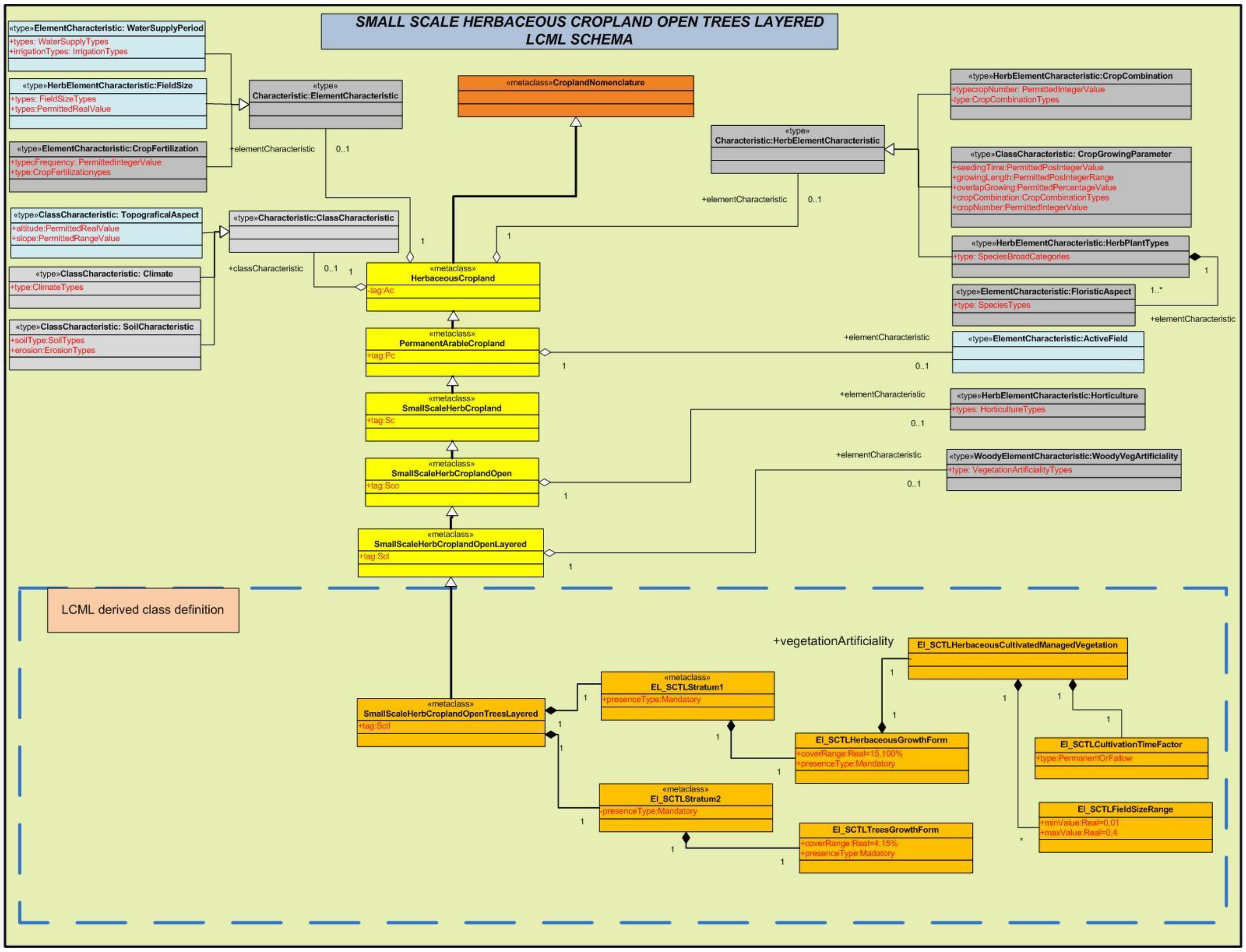


Fig.61 UMl of the class *Small scale herbaceous cropland trees layered*

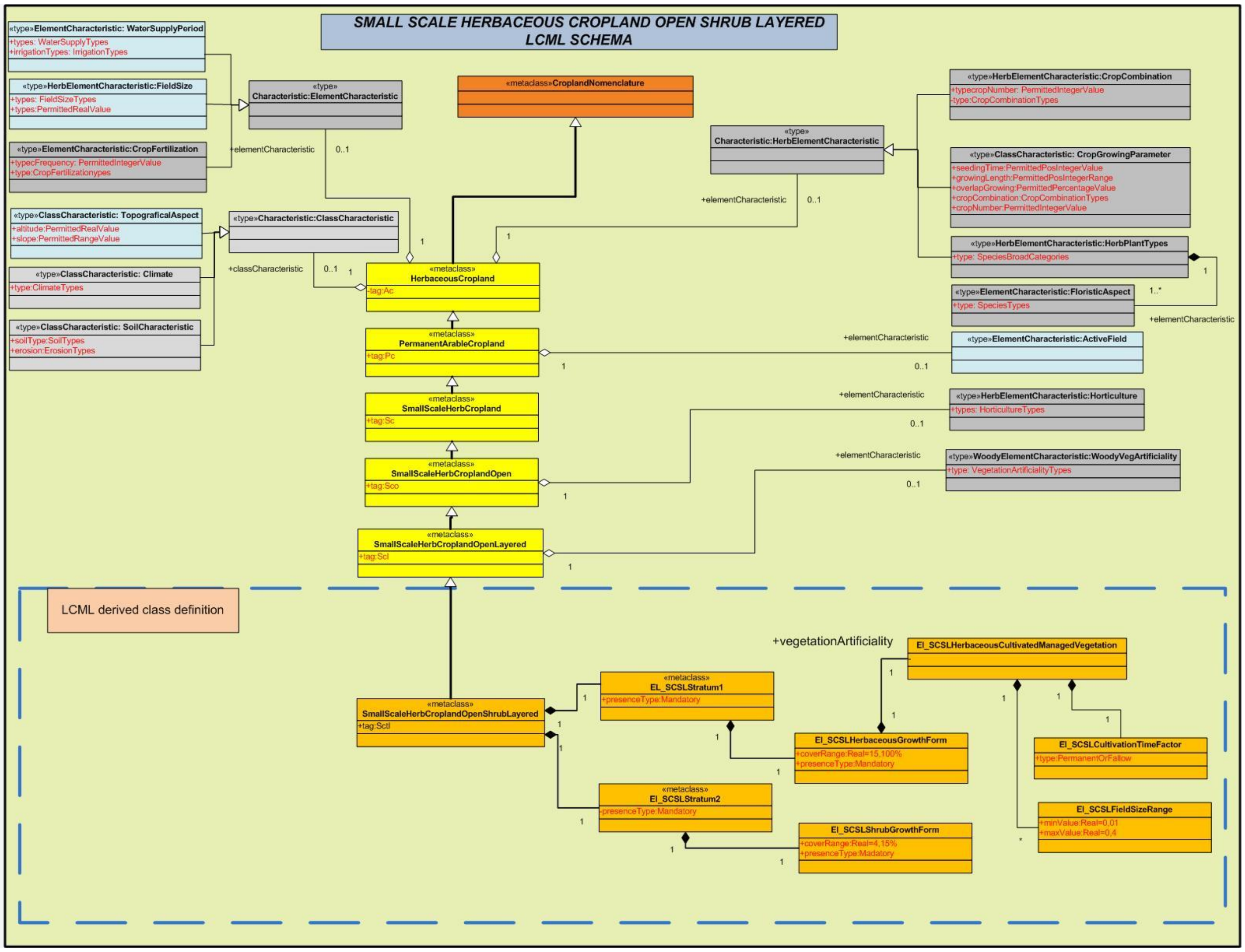


Fig. 62 UMl of the class *Small scale herbaceous cropland open shrub layered*

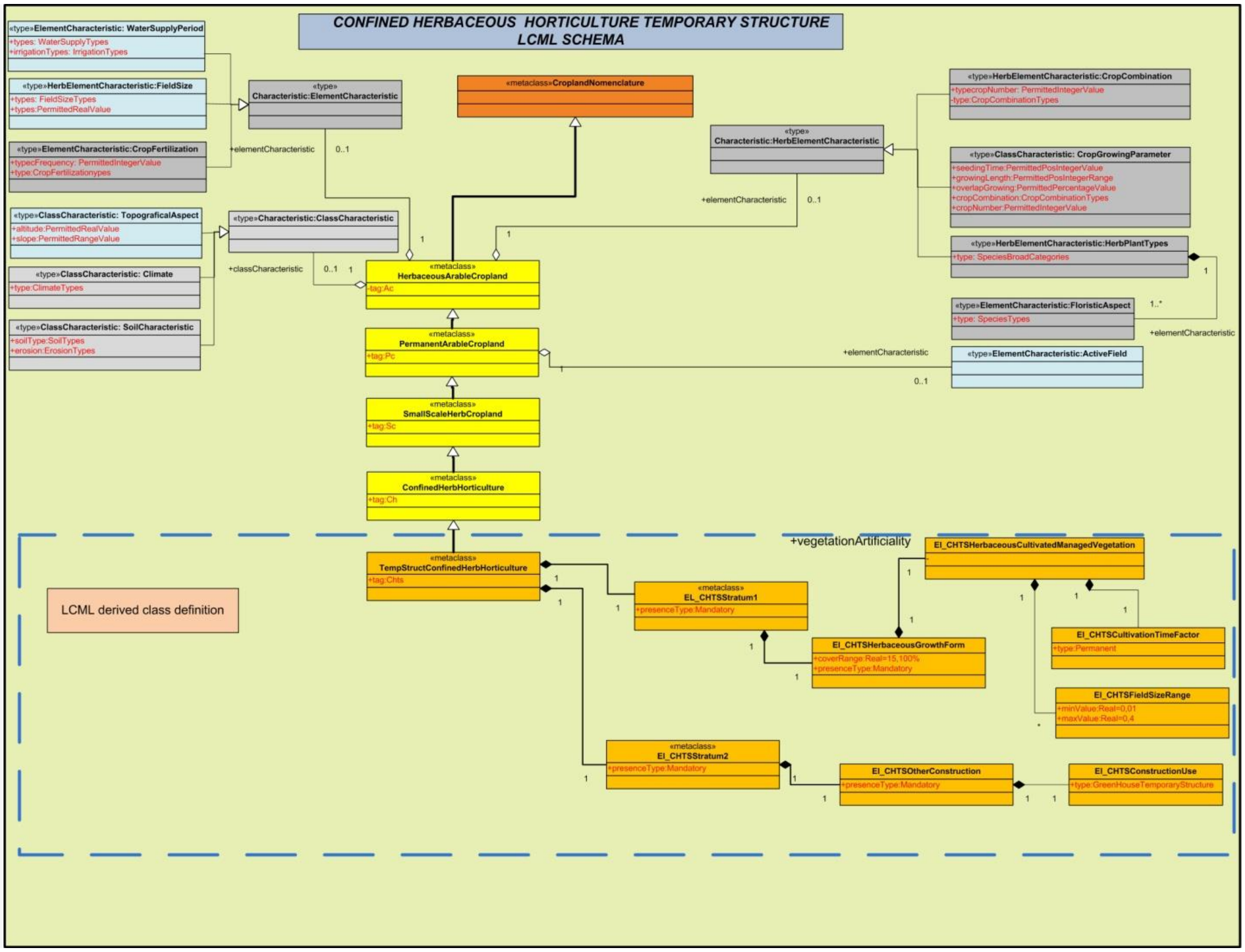


Fig.63 UMl of the class *Temporary structure confined herbaceous horticulture*

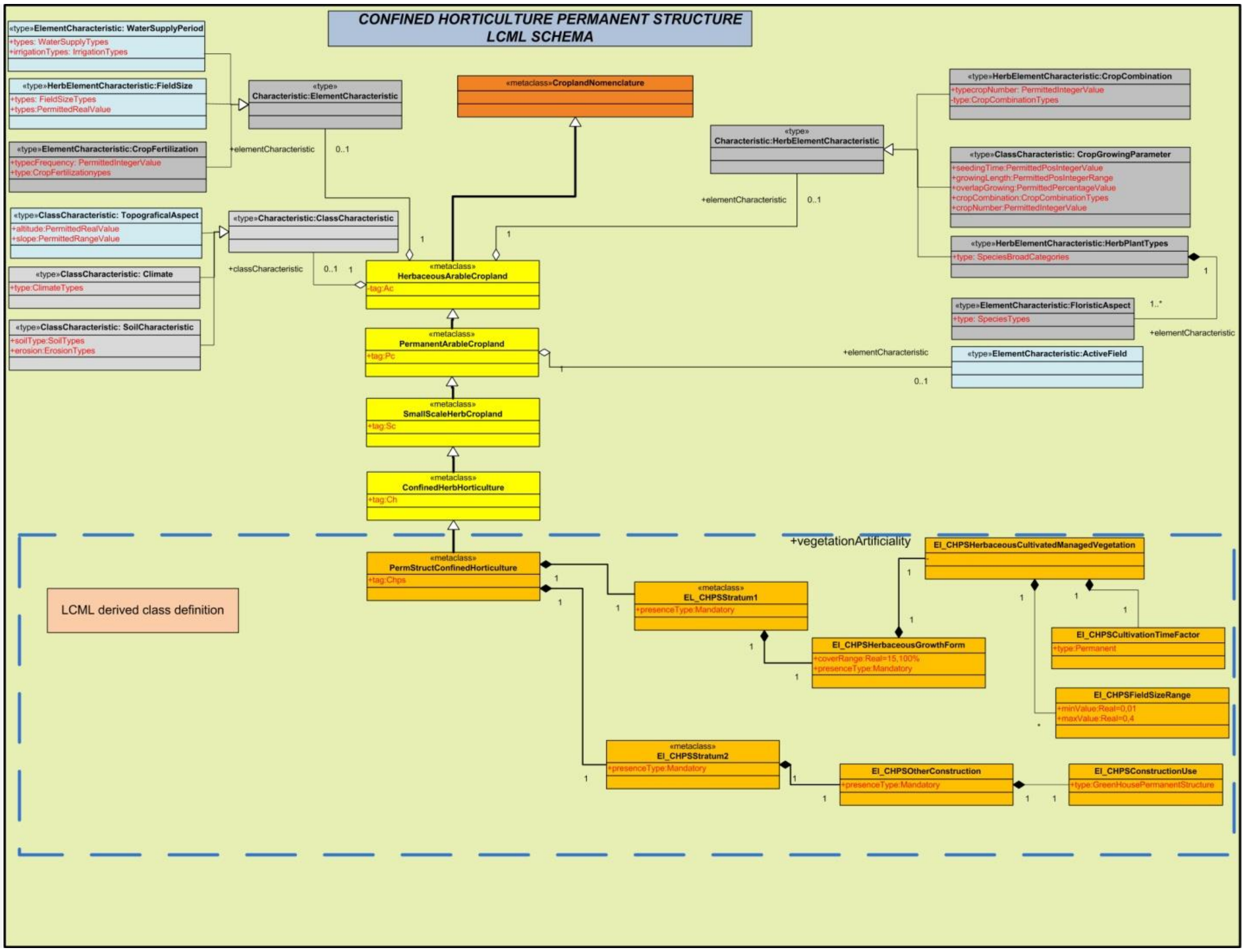


Fig. 64 UMl of the class *Permanent structure confined herbaceous horticulture*

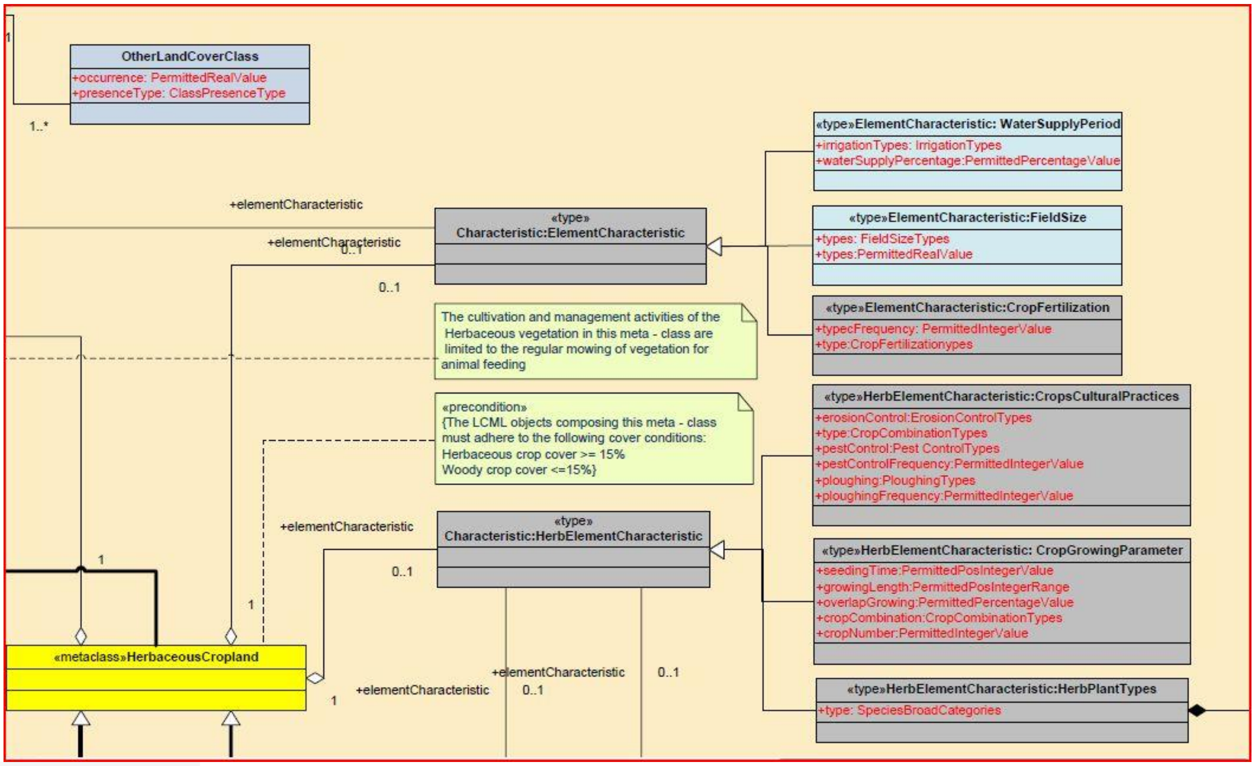


Fig. 65 box 5

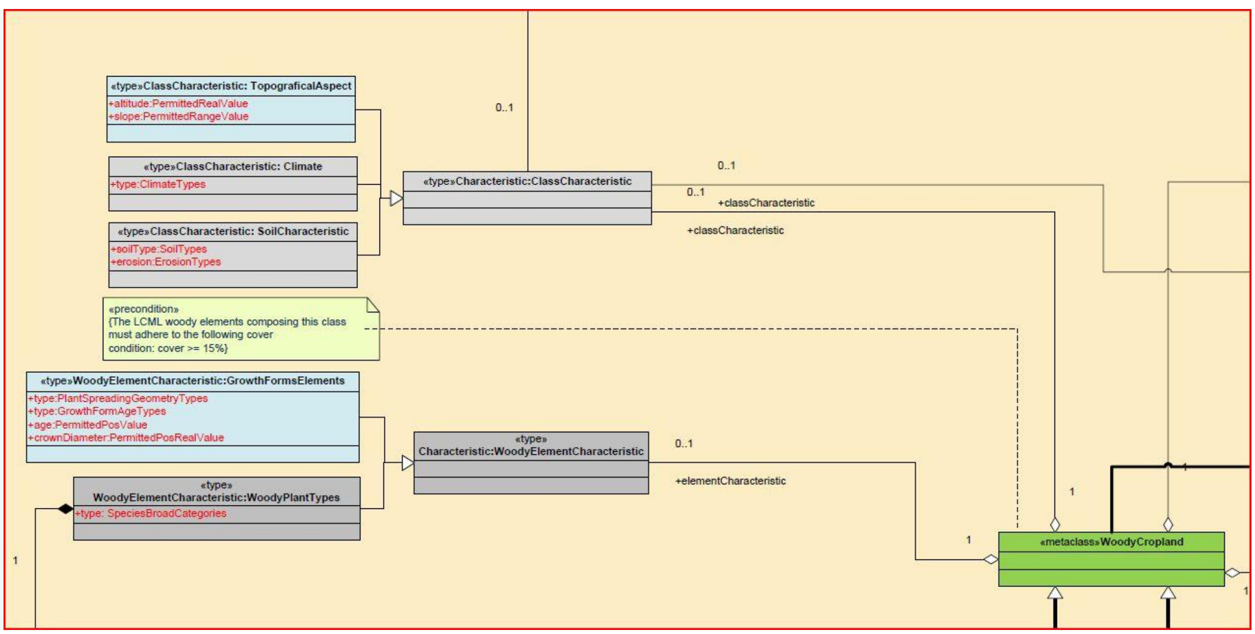


Fig.66 box 6

Both fig. 65 and 66 represent the portions of the UML were the whole extra characteristics to be linked at different levels to the classes are shown.

Annex 2 Glossary of land cover meta-elements and characteristics

A.1 Glossary Introduction

This glossary contains a set of definitions that may be used with the LCML meta-elements defining the meta-classes described in the UML model. The definitions are grouped in generally the same order as the model is described, however since some terms are used multiple times in the model, such as for characteristics, the order does not match exactly.

LCML meta - elements

Growth Forms

A Growth Form is a group of plants having certain morphological features in common (Kuechler and Zonneveld, 1988). The LCML allows the height and percentage cover of the different Growth Forms to be specified.

Cover

Cover is expressed as a percentage of area covered by the growth form. It is a proportion of the ground, substrate or water surface covered by a layer of plants, considered at the greatest horizontal perimeter level of each plant in the layer. [11]

Growth form types

A distinction can be made between the different plant growth forms on basis of their *physiognomic* aspects. Woody plants (*sub-divided into* Trees, Shrubs *and* Woody) are *distinguished from* Herbaceous (*which are sub-divided into* Forbs *and* Graminoids), Lichens/Mosses and Algae *Growth Forms*. Additional growth form criteria can also be used to undertake a further sub-division, for example: the quality of the main axis of shoots can be used to distinguish Woody from Herbaceous; branching symmetry to distinguish Trees from Shrubs; and physiognomy of the herbaceous plants to distinguish Forbs from Graminoids and Lichens/Mosses. [27] [19]

Woody

Perennial plants with stem(s) and branches from which buds and shoots develop are defined as woody. [15] Semi-woody plants are included here.[11] Depending on the branching symmetry, a distinction is made between Trees and Shrubs.[27] With reference to the International Classification and Mapping of Vegetation,[31] bamboos and tuft plants (palms, tree ferns, etc.) can also belong to this category. Depending on their height, they are classified as Trees or Shrubs.

Trees

A tree is defined as a woody perennial plant with a single, well-defined stem carrying a more-or-less-defined crown and is at least 2 m tall.[15]
A condition of Height is applied to separate Trees from Shrubs: woody plants higher than 5 m are classified as Trees. In contrast, woody plants lower than 5 m are classified as Shrubs. This general rule is subject to the following exception: a woody plant with a clear physiognomic aspect of a tree can be classified as Trees even if the Height is lower than 5 m but more than 2 m. In this case, a sub condition of physiognomic aspect is added to the Height condition.
NOTE Plants essentially herbaceous but with a woody appearance (e.g. bamboos and ferns) are classified as Trees if the height is more than 5 m and as Shrubs if the height is less than 5 m.

Shrubs

Shrubs are woody perennial plants with persistent woody stems and without any defined main stem, being less than 5 m tall.[15] The growth habit can be erect, spreading or prostrate.
A condition of Height is applied to separate Trees from Shrubs: woody plants higher than 5 m are classified as Trees. In contrast, woody plants lower than 5 m are classified as Shrubs. This general rule is subject to the following exception: a woody plant with a clear physiognomic aspect of trees can be classified as Trees even if the Height is lower than 5 m but more than 2 m. In this case, a sub condition of physiognomic aspect is added to the Height condition.
NOTE Plants essentially herbaceous but with a woody appearance (e.g. bamboos and ferns) are classified as Trees if the height is more than 5 m and as Shrubs if the height is less than 5 m. In addition for the classifier Woody (indistinct and/or intricate mixture of trees and shrubs), the higher limit is set at 7 m and the lower one at 2 m. This category includes: other Woody plants that are not 'shrub like' (e.g. ground lianas), Welwitschia and plants that are definitely not herbaceous (e.g. agave and factoids).

Herbaceous General

Plants without persistent stem or shoots above ground and lacking definite firm structure are defined as herbaceous.[25] There are two categories, depending on the physiognomy, namely *Graminoids* and *Forbs*.[19]

Natural and semi-natural vegetation

Natural vegetated areas are defined as areas where the vegetative cover is in balance with abiotic and biotic forces of its biotope. *Semi-natural vegetation* is defined as vegetation not planted by humans but influenced by human actions. These may result from grazing, possibly overgrazing the natural phytocenoses, or else from practices such as selective logging in a natural forest whereby the floristic composition has been changed, also previously cultivated areas which have been abandoned and where vegetation is regenerating are included. The human disturbance may be deliberate or inadvertent. *Semi-natural vegetation* includes thus, vegetation due to human influences but which has recovered to such an extent that species composition and environmental and ecological processes are indistinguishable from, or in a process of achieving, its undisturbed state. The vegetative cover is not artificial and it does not require human activities to be maintained over the long term.

Cultivated and Managed Vegetation General

Cultivated and Managed Vegetation are areas where the natural vegetation has been removed or modified and replaced by different types of vegetative cover resulting from anthropic activities. This vegetation is artificial and requires human activities to be maintained over the long term. In between the human activities, the surface can be temporarily without vegetative cover. Its seasonal phenological appearance can be regularly modified by humans (e.g. irrigation). All vegetation that is planted or cultivated with the intent to harvest is included in this class (e.g. wheat fields, orchards, rubber and teak plantations). Afforestation is not considered in this class because although it is planted there is no regular modification of the cover.

Plantation

Plantation is usually a large farm or estate mainly planted with trees and shrubs but can include the production of other agricultural products. This quality can be further subdivided into:

- **Forest Plantation**: is for the production of high volume of wood in a short period of time.
- **Orchard** and other plantation: this category includes orchards which are plantation normally devoted to the production of fruit and nuts and any other types of plantations

Built up surface

Built-up areas are characterized by the substitution of the original (semi-)natural cover or water surface with an artificial, often impervious, cover. This artificial cover is usually characterized by long cover duration. This metaclass can be sub-divided into *linear* and *non-linear* surfaces. This category is typified by natural or artificial materials continuously covering the surface, or the soil surface is modified to such an extent that it can no longer be considered as land. In many cases, these structures form a network that covers the land surface. This surface can consist of hard artificial materials, concrete, gravel or hardened soil or a mixture of any of these materials.

Non linear surface

This category describes built-up areas where non-linear artificial constructions cover the land with an impervious surface. The constructed materials may be made up of either of "*Hard Materials*" or "*Light Materials*". A percentage of cover over the ground occupied by the construction can be specified by the user.

— **Hard material**: are structures made out of cement, iron or other hard types of construction materials.

— **Light material**: light wood, plastic and other light materials used to build light constructions such as greenhouses and light wooden prefabricated buildings.

Water salinity

Water salinity is described according to the concentration of Total Dissolved Solids (TDS), expressed in parts per million (ppm), giving the following classification:

—

— **Fresh**: less than 1 000 ppm TDS.

— **Slightly saline**: 1 000 – 3 000 TDS.

— **Moderately saline**: 3 000 – 10 000 TDS.

— **Very saline**: 10 000 – 35 000 TDS.

— **Brine**: more than 35 000 ppm TDS (= water saturated or nearly so with salt).

Class characteristics:

Climate: the present climate attribute is classified according to the Agro-Ecological Zoning as developed by FAO using two items:

— thermal climate

1. Tropics

Monthly mean temperature (T_{mean}) more than 18°C in every month.

2. Subtropics – Summer Rainfall

(T_{mean}) in every month more than 5°C and at least one month with T_{mean} less than 18°C

Precipitation (P) concentrated in summer (P_{summer} more than P_{winter}).

3. Subtropics – Winter rainfall

As for 2, but P_{winter} more than P_{summer}.

4. Temperate Oceanic

Four or more months have T_{mean} more than 10°C and at least one month has T_{mean} less than 5°C.

The difference between the T_{mean} of warmest and coldest month is less than 20°C.

5. Temperate Continental

As for 4, but the difference between T_{mean} warmest and coldest is more than 20°C.

6. Boreal Oceanic

One to four months have T_{mean} more than 10°C and at least one month has T_{mean} less than 5°C. Difference in T_{mean} between warmest and coldest month is less than 20°C.

7. Boreal Continental

As for 6, but difference in T_{mean} between warmest and coldest months is more than 20°C.

8. Polar/Arctic

All months have a T_{mean} less than 10°C.

— length of growing period:

This is the period of the year that moisture and temperature are not limiting crop growth. In technical terms, it is calculated as the period starting when rainfall is more than 0.5 of potential evapotranspiration (PET) or T_{mean} is grater than 5ºC, whichever comes last, and ends when a maximum soil moisture storage of 100 mm has been depleted or rainfall is less than 0.5 PET or T_{mean} is less than 5ºC, whichever comes first. The growing period can be broken by a dormancy period. Killing temperatures, snow cover and a soil moisture depletion factor are all taken into account in the calculation.

The following classes are suggested:

- **Hyperarid:** LGP = 0 days
- **Arid:** LGP = 1 - 59 days
- **Dry Semi-Arid:** LGP = 60 -119 days
- **Moist Semi-Arid:** LGP = 120 -179 days
- **Subhumid:** LGP = 180 - 239 days
- **Humid:** LGP = 240 - 329 days
- **Perhumid:** LGP more than 330 days

Topographical aspects: limited to *altitude* expressed in a range value in meters and *slope* expressed in a range value in degree

Soil characteristics: limited to *soil types* (according to FAO soil classification) and *erosion types* as follows:

> ***no visible sign of erosion:*** no visible traces of erosion can be recognized on the surface.
>
> ***Visible sign of erosion:*** visible traces of erosion can be recognized on the surface but are not further specified. A further specification can be made into:

— Water Erosion,

— sheet erosion,

— rill erosion,

— gully erosion,

— Wind Erosion and

— Mass Movement.

Water supply period: defined in *irrigation types*:

Through the Water Supply Period quality a distinction can be made between rain fed, post-flooding and irrigated practices being used for a specific layer:

- **Rainfed**: Water supply is completely determined by rainfall.
- **Post-Flooding**: After rainwater has flooded the field, the water infiltrated into the soil is used intentionally as a water reserve for crop cultivation. The crop(s) use(s) this water reserve for establishment.
- **Irrigated**: Any of several means of providing an artificial regular supply of water, in addition to rain, to the crop(s). Irrigated can be further subdivided into three main irrigation methods:

— **Surface Irrigation**: Water is supplied to the field(s) to form a water layer that infiltrates slowly into the soil. The field may be wetted completed (borders, basins) or partly (furrows, corrugations). The water layer may be moving during irrigation (flow irrigation) or it may be mainly stagnant (check irrigation).

- **Sprinkler Irrigation**: Water is pumped up from a source into a closed distribution network and then conveyed over the soil surface and crops. The irrigation water is applied by means of rotating sprinklers, perforated pipes, sprayers or spinners that are connected to the network. The distribution networks may be permanent, portable or a combination of the two.

- **Drip Irrigation**: This type of irrigation is also called trickle, dribble or localized irrigation. The water is applied at very low pressure through a network of plastic tubes running along the surface or buried. The network consists of main lines and laterals.[12] The water trickles onto the soil near the plant(s) at a confined spot

and *irrigation percentage* expressed in % range values

Field size: defined as *field size types:*

Small fields: area less than 2 ha
Medium fields: area between 2 and 5 ha
Large fields: area more than 5 ha

and *field size* expressed in range value in meters.

Crop fertilization defined as: the concentrated sources of plant nutrients that are added to growing media. These can be "straight" fertilizers containing only one of the major nutrients (nitrogen, phosphorous, potassium or magnesium) or "compound" fertilizers which supply two or more nutrients. [1] The two main classes which a user can distinguish in LCML are defined under *fertilization types* as follows:

- **Organic**: which implies that the fertilizer is derived from living organisms of fertilizers and includes manure, slurry, worm castings, peat, seaweed and sewage. Manufactured fertilizers such as compost, bloodmeal, bone meal and seaweed extracts are also considered organic.

- **Inorganic**: fertilizers are those derived from non living materials usually made of simple inorganic chemicals or minerals

NOTE Some ambiguity in the usage of the term 'organic' exists because some of synthetic fertilizers, such as urea and urea formaldehyde, are fully organic in the sense of organic chemistry. In fact, it would be difficult to chemically distinguish between urea of biological origin and that produced synthetically. On the other hand, some fertilizer materials commonly approved for organic agriculture, such as powdered limestone, mined rock phosphate and Chilean saltpeter, are inorganic in the use of the term by chemistry.

and *fertilization frequency* expressed in range value of months.

Characteristics related to ***Woody LCML*** element:

Woody growth form characteristics defined as: *plant spreading geometry types* divided in*:*

- Regular: the Growth Forms have an ordered and distinguishable geometry (for example rows trees in an orchard).
- Irregular: the Growth Forms within the strata have no specific regular arrangement.

and growth form age defined as: the age of a specific vegetative layer which is specified in months/years. The user can also specify if the there is an "Even age" within the Growth Form strata or an "Uneven age". For the "Uneven age" the percentage of each group of plants having the same age is allowed.

and *crown diameter* expressed in a range value in meters.

Rotation cycle: (for *forest* plantation class) is expressed in

rotation type (short 5-15 years, medium 15-30 years, long more than30 years),

rotation years expressed in range value in years.

Woody plant types: indicated in *species broad categories* (user defined) and/or specific floristic *species name*.

Characteristics related to Herbaceous ***LCML*** element (the following characteristics are also additionally linked to the herbaceous LCML element of the meta - class ***Trees orchards and other plantations intercropped*** and ***Shrub orchards and other plantations intercropped*** :

Crops cultural practices: expressed in *erosion control types as follows*:

— **Contour ploughing**: is the practice of ploughing across a slope following its contours. The rows formed prevent water run-off and the formation of streams and gullies.

— **Terracing**: In hilly areas and series of level terraces are built into the hill side, giving a stepped appearance. This prevents soil erosion and rapid surface runoff.

— **Wind break**: Windbreaks are usually made up of one or more rows of trees or shrubs planted, often around hedges of fields on farms, to provide shelter from the wind.

Cultivation time factor: indicates for how much of the growing season(s) the land is covered by crops. A distinction is made between:

- *Shifting cultivation*: it describes the growing of crops for a few years on selected and cleared plots, alternating with a lengthy period of vegetative fallow when the soil is rested. The land is cultivated for less than 33 percent of the time (Ruthenberg, 1980). This cover by is followed by the vegetative and/or bare cover of the fallow period that can last for several years (Shaner *et al.*, 1982).

- *Fallow system* : an agricultural system with an alternation between a cropping period of several years and a fallow period. The land is cultivated for between 33 and 66 percent of the years, which means a percentage of 50 percent is given by three, five or ten years of crop cover followed by three, five or ten years of fallow vegetative cover (Ruthenberg, 1980).

- *Permanent cultivation*: The crop should cover the land for at least two years. The first harvest takes usually place after one year or later. Under this cultivation system the land is cultivated for more than 66 percent of the years (Ruthenberg, 1980).

pest control types expressed as:

— **Organic**: this is the use of organic agricultural methods, including biological agents such as natural predators, bacteria, fungi and viruses. It also includes microbial biological insecticides, but there are also examples of fungal control agents.

— **Inorganic**: is of non biological origin and include minerals and synthetic products such as certain pesticides.

pest control frequency expressed in range value in months,

and *plouging* defined as: the turnover of the upper layer of the soil, bringing fresh nutrients to the surface, while burying weeds and the remains of previous crops, allowing them to break down. It also aerates the soil, and allows it to hold moisture better. In modern use, a ploughed field is typically left to dry out, and is then harrowed before planting. The plouging practices are differentiated according to *plouging types* as:

— **Manual**: ploughing is undertaken using hoes and other hand operated utensils.

— **Manual/animal**: ploughing which is undertaken with the use of animals (such as horses, oxen, donkeys, etc.) to provide the physical power to pull the plough which is guided by a human handler.

— **Mechanical**: ploughing undertaken using mechanized machinery with engines such as tractors.

and *ploughing frequency* expressed in range value in months.

Crop growing parameters: including:

seeding time, *growing length* both expressed in range value in months and *overlap growing* expressed in % range value, *crop combination*, defined as the cultivation of two or three crops which are growing with the following pattern status:

— Simultaneously (more than one crop is cultivated at the same time in a defined area. This is often indicated as mixed cropping. Therefore the different crops can be intermingled or they grow in distinct patterns on the same field.)

— with a period of overlap (planting or sowing one crop into another crop which has reached an advanced growing stage but before the harvest of the first crop (Lipton, 1995),

— Sequentially on the same field (the growing of two or more crops in sequence on the same field within one growing season. The succeeding crop is planted after the preceding one is harvested). Crop intensification is both in time and space (vertical and horizontal). No horizontal spatial arrangement of the crops (e.g. rows, strips or no arrangement) is considered.

crop number expressed in real number value.

Herbaceous plant types: indicated in *species broad categories* (Graminoids and forbs) and/or specific *floristic species*.

Active fields: defined as the areas were during the observation time (a year or a season) a crop has been cultivated.

Water body periodic variations: expressed as

— period type (defined in: daily, tidal, atmospheric pressure, user defined),

— *persistence type* expressed in real number

— *Persistence unit* defined in unit types (year, month, day or hours).

Water deepness: expressed as *deepness types:*

- — *Shallow* (water level up to 40 cm deep)
- — *Deep* (water level more than 40 cm. deep)

Aquaculture: expressed as *aquaculture types* (user defined)

Woody vegetation artificiality: expressed as *vegetation artificiality type* (cultivated or natural/semi natural)

Horticulture: expressed as *horticulture types*:

- — Horticulture according to the main crop type it divides in: floriculture (growing of flowers), pomology (tree and fruit cultivation), olericulture (growing of vegetables and non woody plants for food) landscape horticulture (cultivation of ornamental plants).
- — Market gardening: is the relatively small scale production of fruits, vegetables and flowers as cash crops, frequently sold directly to consumers.
- — Urban horticulture: includes all horticultural crops grown for human consumption and ornamental use within and in the immediate surroundings of cities.
- — Roof top garden: includes any type of gardening on the roof of a building
- — User defined

Hydro culture (growing of plants in a soil less medium or an aquatic based environment is further divided in *hydro culture types*:

- Hydroponics in solution culture: do not use any medium for the roots, only the nutrient solution
- Hydroponics in medium culture: a solid medium is used for the roots.

Horticulture structure expressed as *structure types*:

— Temporary: light (usually) plastic structure removed (or removable) after one or more cultivation cycles

— Permanent: long term structures having different types of covering materials.

Annex 3 How LCML works

LCML acts as a method to bring the Land Cover community together to create a common understanding of land cover nomenclatures with the aim to produce global regional and national data sets able to be reconciled at different scales and detail level and geographic places.

The LCML provides a general framework of rules from which more exclusive conditions can be derived to create specific legends. It is a language based on physiognomy and stratification of both biotic and abiotic materials. The system may be used to specify any land cover feature anywhere in the world, using a set of independent diagnostic criteria that allow correlation with existing classifications and legends.

LCML Land cover classes are defined by a combination of a set of land cover elements. These land cover meta-elements are divided in two categories "basic elements" the elements that constitutes the main physiognomic aspects of biotic and abiotic cover features, for instance for biotic features trees, shrubs, herbaceous vegetation etc., and "element properties" that further define the physiognomic/structural aspect of the basic objects.

LCML fundamental idea is that: a predefined set of LCML basic elements (BIOTIC and ABIOTIC) and their properties enriched in their semantic significance with "element" and " class" characteristics can be arranged in different types of vertical and horizontal patterns to describe a wide variety of distinctive and detailed land cover situations (see fig.67)

Fig. 67. This example describes the formation of a land cover class using different vegetation layers. Savannah vegetation is usually composed by a combination of sparse trees and shrubs over a grassland area. Three separate layers of Trees, Shrubs and Herbs with different cover of the woody component type.

The model in fig. 67a shows how the class EL_Savannah is modeled using the LCML rules. The class has been built up with three separate vegetation layers: a layer of herbaceous vegetation with a cover ranging from 50 to 100%, a layer of trees with cover from 4 to 15 % and a layer of shrubs with open cover from 4 to 15%.

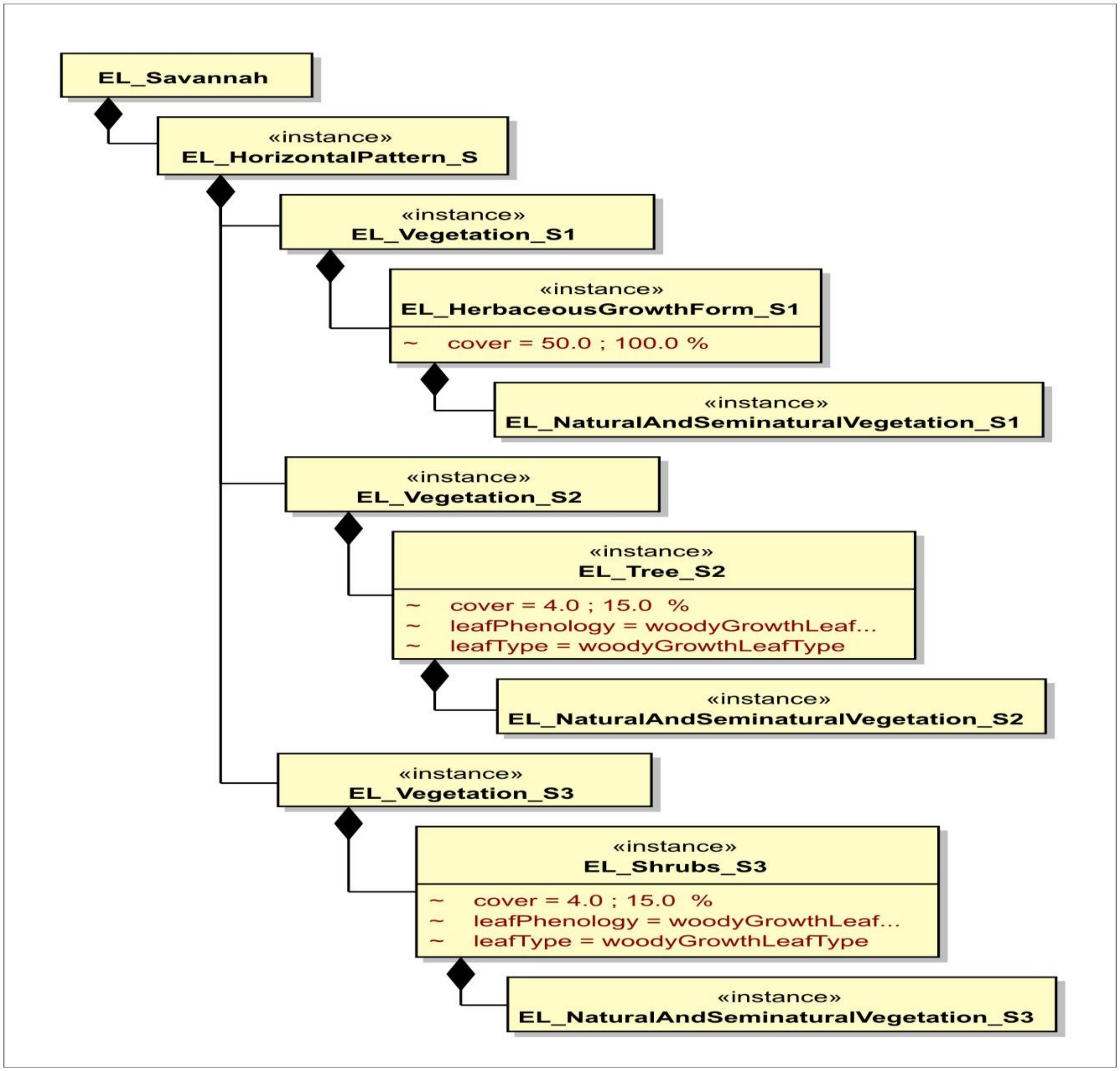


Fig. 67a

Figure 68.This example describes a Mangrove Swamp. This situation can be modeled by the combination of two layers with vegetated and abiotic elements further described by their characteristics. This solution can easily represent a type of “flooded or regularly flooded vegetation” without the use of complex definitions.

Fig.68

The model illustrated in Figure 69 shows the class EL_Mangrove that describes according to the UML rules the example shown above. The class EL_Mangrove has been built up with a layer of Broadleaved Deciduous trees growth with cover from 70 to 90 %, height from 5 to 7 m, and a layer of water (brackish) with a height from 0, 2 to 1 m. Further descriptive elements can be added to both the vegetated and abiotic strata (floristic aspect, water periodic variations etc.)

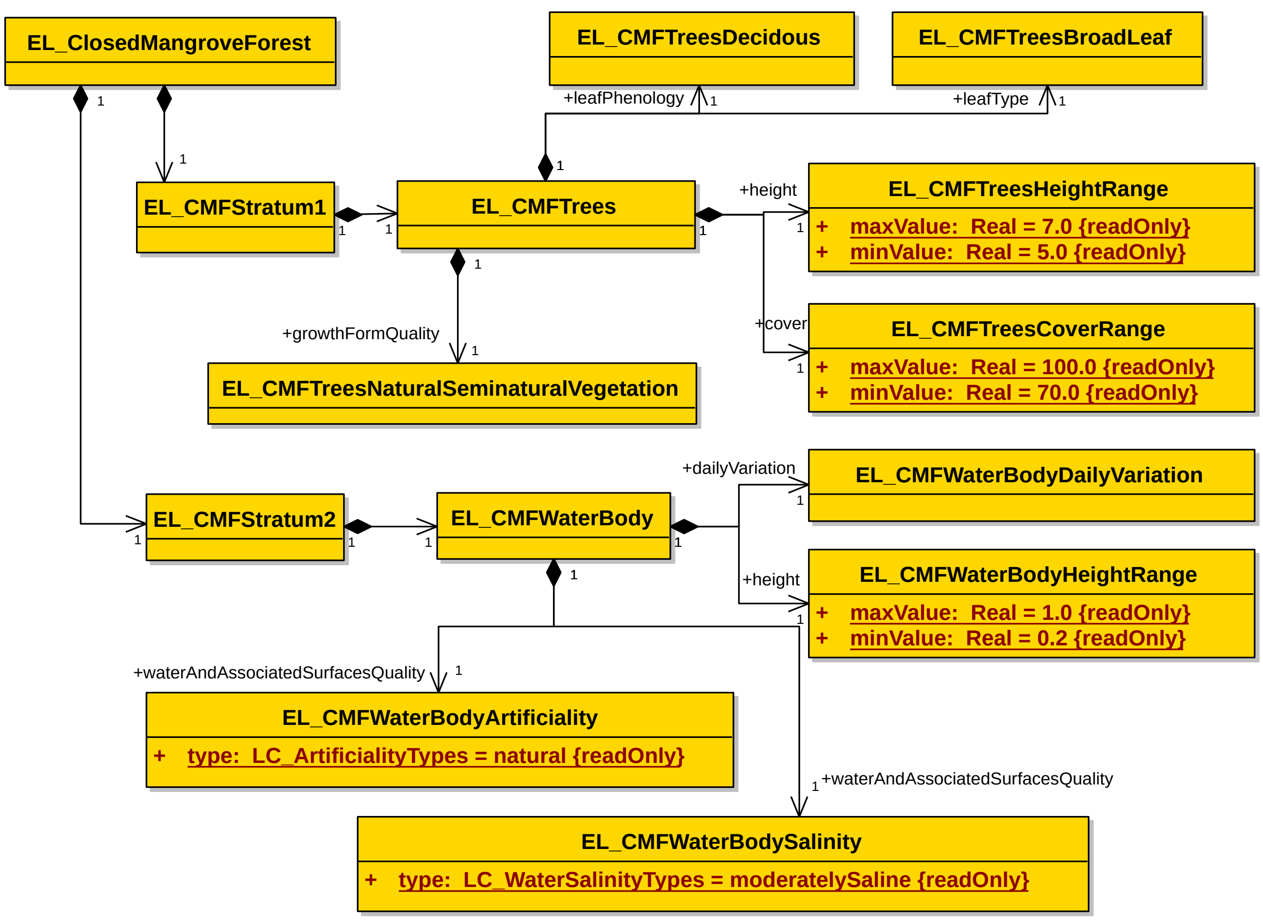


Fig. 69

Fig. 70. This example describes a boreal and hemi-boreal forest system where the tree layer is in two different heights. The trees are in two parts, the overstore trees, the understory trees, and a separate shrub layer and forbs layer. The model illustrate below shows how the class EL_BorealAndHemiborealForest is modeled using the UML rules. The class has been modeled with four vegetation layers consisting of two layers of trees, a layer of shrubs and a layer of forbs. This example has been kept very simple and no attributes have been used to characterize the trees, shrubs or forbs, no height, cover or Leaf type/leaf phenology attribution has been used in order to remain very general. . An additional UML element describing the climatic area could have been added but is not included in the example for simplicity.

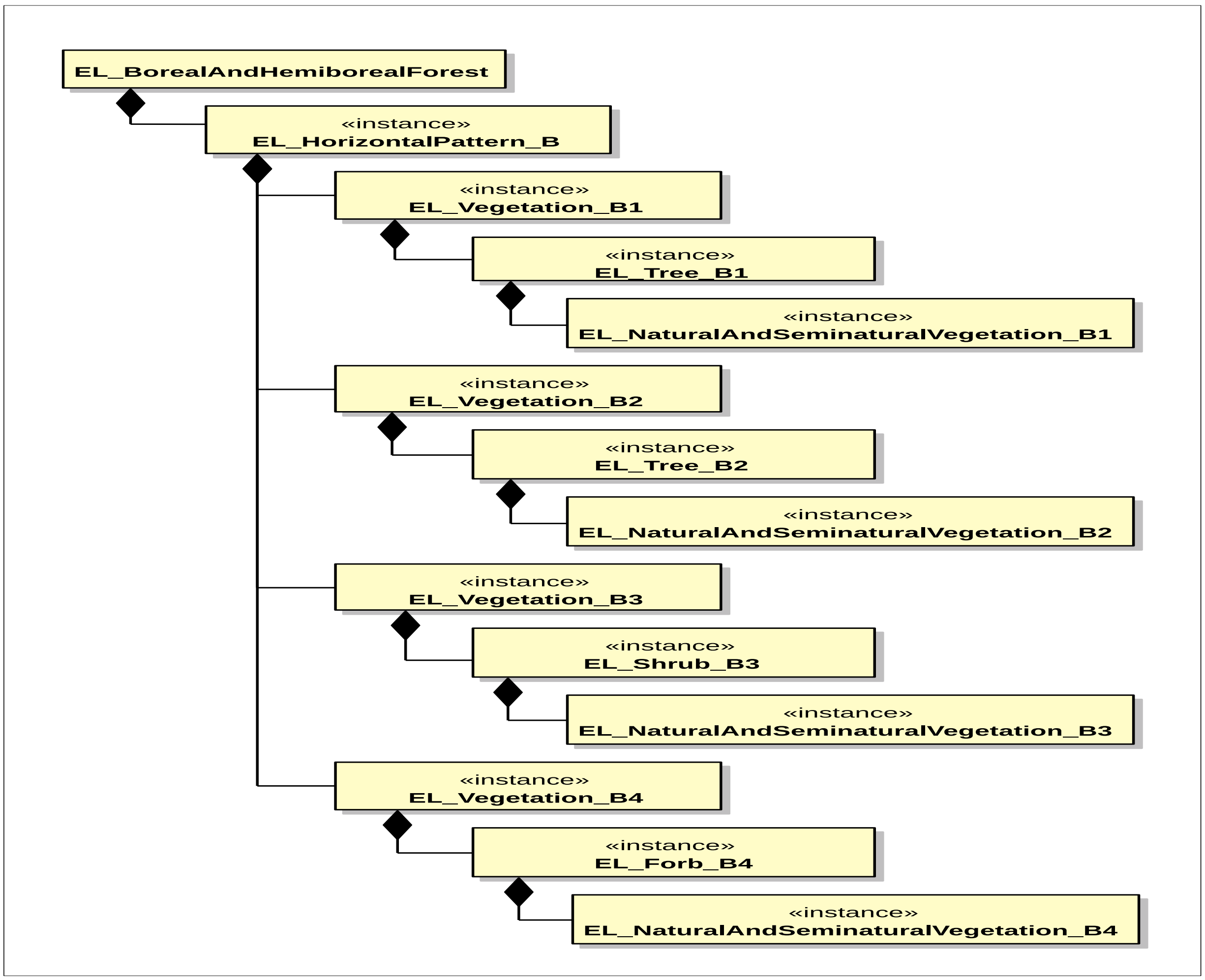


Fig. 70

Further definition of the land cover metaclasses may be achieved by adding the LCML element characteristics. The characteristics are of two types land cover element characteristics and land cover class characteristics. “LC_ClassCharacteristics” and “LC_ElementCharacteristics” are defined as optional descriptive elements not directly

related to the physiognomic/structural characterization of the land cover meta-element. “LC_ElementCharacteristics” may be applied to a single basic meta-element. “LC_ClassCharacteristics” relate to a whole Land Cover class, defined as the combination of single or multiple strata of single or multiple basic meta-elements. The definition of these characteristics in this international standard is informative, not normative. That is, other sets of characteristics may be established and used with the LCML basic elements. These characteristics do not in any way prescribe how a Land Cover Classification System is to be established. When used they can assist in better defining a land cover class and therefore make it easier to compare classes between LCCSs.
The metalanguage generates mutually exclusive land cover classes, with specific rules to deal with the all functional elements of the language (basic meta-elements and properties) and the different strata.

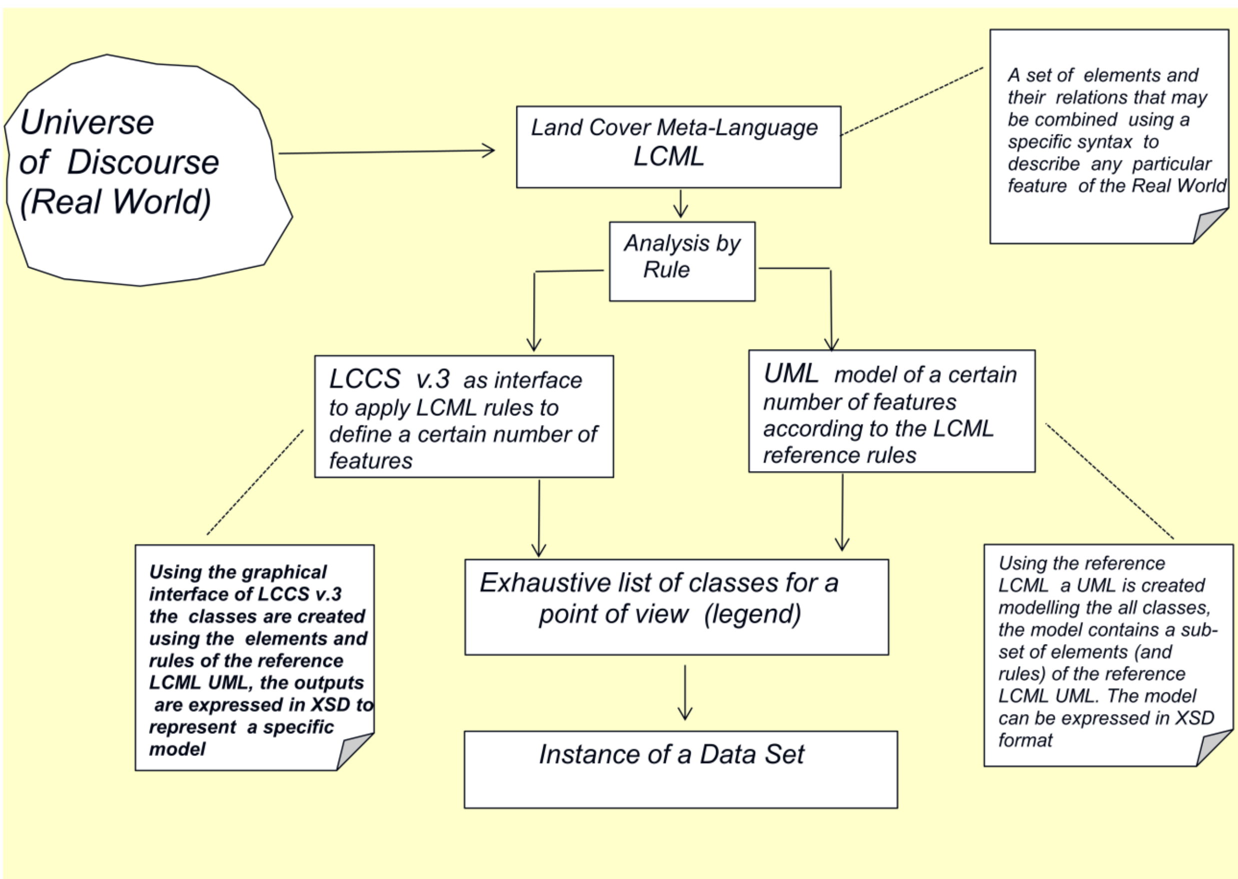


Fig.71

Finally in fig. 71 the functional relationship between LCML and LCCS v.3 is shown. LCCS 3 is basically a graphic interface tool to apply the set of rules and conditions present in the LCML schema.

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