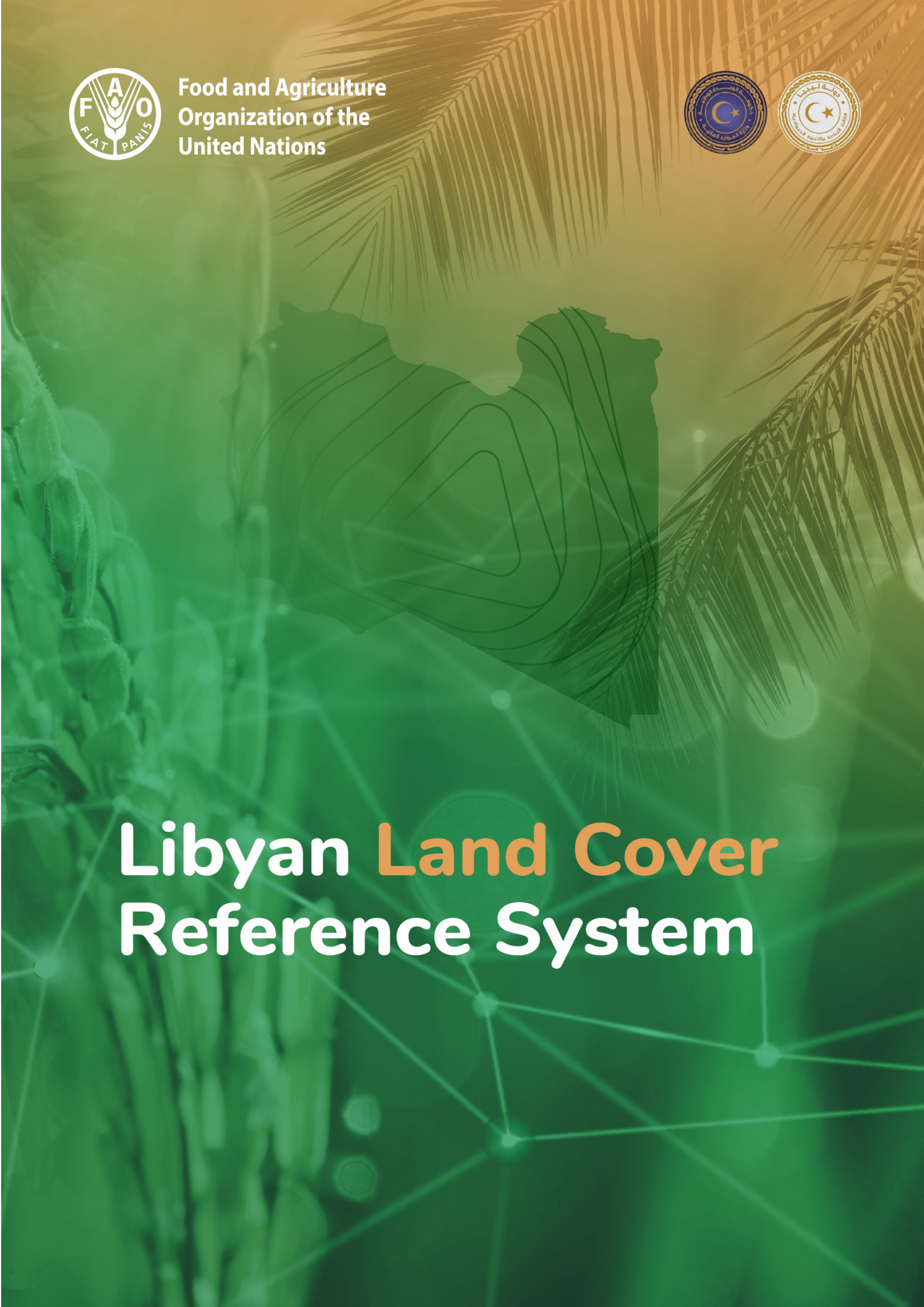
Food and Agriculture
Organization of the
United Nations
Libyan Land Cover
Reference System

Libyan Land Cover Reference System

by

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Foreword 1

In Libya, the average food consumption patterns of household's remain relatively high, low levels of coping capacity suggest that the current situation will deteriorate. Involvement in agriculture will continue to play a vital role in contributing to food security as households face increasing difficulties.

The crisis has exacerbated pre-existing challenges associated with agricultural production, including water scarcity, animal and plant diseases, desertification and labour shortages. In addition to these longer-term challenges, the crisis has ruptured market linkages and disrupted access to water, electricity, inputs, and transportation.

In Libya, crop and livestock production are a significant source of food security for many households, which tend to be small producers. Despite agriculture's relatively small contribution to Libya's gross domestic product (GDP), the proportion of Libyans engaged in some form of agricultural production is comparatively large around 22 percent. In spite of this, participation in agriculture may have been considerably higher before the crisis, however, with approximately 7.5 percent of the population abandoning agricultural activities since 2014.

In addition to that, Libya has undergone rapid, wide- ranging changes in the land use and land cover intensified by the conversion of natural resources for food purpose, urbanization, and other socioeconomic benefits. The use of geographic information system (GIS) and remote sensing techniques to gain a quantitative understanding of the spatiotemporal dynamics of land use and land cover in Libya is nowadays a must to be able to analyze the major factors behind land use and land cover changes and decline of natural vegetation. The libyan land cover reference system will promote a comparison approach to detect land use and land cover changes during different decades. These changes will focus mainly on expanse of the natural Mediterranean forest, deforestation, orchards and rain-fed agriculture lands, land under irrigated crops, area of urban and built-up land and bare and low vegetation lands.

It is strongly recommended that urgent measures be taken to conserve the natural forest and to achieve a rational use of agricultural land in all the country.

HUSAYN AT A ALQATRANI
Vice Prime Minister and Acting Minister of Agriculture and Livestock

Foreword 2

land cover and Land use is one of the fourteen themes considered by the United Nations Committee of Experts on Global Geospatial Information Management (UNGGIM) as fundamental to strengthening a country's geospatial information infrastructure. Data on land cover and land use is key to monitor progress on a number of SDG targets, inform on land management impacts or allow planning at regional or local level. It is therefore critical to address the land cover theme in all countries building on international standards and the latest geospatial technologies and innovations. Advances on geospatial science with increased number of Earth observation programs, cloud computing platforms and machine learning, allow the development of workflows that generate land cover datasets faster and with more accuracy at global, regional and local scales. However, there is still often inconsistency on land cover classification schemes, uncertainty on their accuracy and lack of interoperability among datasets.

FAO is contributing to the development of tools, standards, and methodologies to empower local stakeholders to develop land cover datasets. The availability of accurate information on soil quality, land use, land cover, vegetation, and water resources can help policymakers and land managers make informed decisions on land management practices. In Libya, the most conspicuous symptoms of the negative impact of land degradation on food production are stagnating and declining yields and agricultural livelihood. There is an increasing need and interest to strengthen national capacities and collaboration for sustainable development through a better understanding of land dynamics.

The Libyan land cover reference system (LLCRS) is developed within the framework of two FAO projects: OSRO/LIB/002/ITA titled: Monitoring, evaluation and rationalization of water use for agriculture sector in Libya funded by Italian agency for development cooperation (AICS) and OSRO/LIB/100/AFB titled: Evaluation of irrigation infrastructure, crop mapping and estimation of agricultural water use in Libya funded by African Development Bank (AfDB). It is the result of a collaboration between the Food and Agriculture Organization of the United Nations (FAO), Ministry of Water Resources, the Ministry of Agriculture and Livestock and the Libyan Centre for Remote Sensing and Space Science and University of Tripoli.

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The Libyan land cover reference system (LLCRS) is the result of an initiative to take a first step towards a harmonized and an international standard i.e. ISO 19144-2 based land cover reference system for creating land cover legend in the country. This reference system has been developed within the framework of the two projects OSRO/LIB/002/ITA (MerWat): Monitoring, evaluation and rationalization of water use for agriculture sector in Libya, funded by the Italian Agency for Cooperation Development (AICS) and OSRO/LIB/100/AFB (IagWat) titled: Evaluation of irrigation infrastructure, crop mapping and estimation of agricultural water use in Libya, funded by the African Development Bank (AfDB), The national system has been supported by various ministries, institutions, and universities including Ministry of Water Resources, Ministry of Agriculture and Livestock, Libyan Centre for Remote Sensing and Space Science and University of Tripoli.

This publication was elaborated through a fruitful collaboration between the Food and Agriculture Organization of the United Nations (FAO), and Ministry of Water Resources, Ministry of Agriculture and Livestock, Libyan Centre for Remote Sensing and Space Science, University of Tripoli, Faculty of Agriculture, University of Tripoli, University of Sebha, University of Fezzan, University of Alshati.

Abbreviations

CERSGIS	Centre for Remote Sensing and Geographic Information Services
CILSS	Comité inter-État de lutte contre la sécheresse au Sahel
ISO	International Organization for Standardization
FAO	Food and Agriculture Organization of United Nations
LCCS	Land Cover Classification System
LCML	Land Cover Meta Language
LCLU	Land Cover and Land Use
LCRS	Land Cover Reference System
RRS	Regional Reference System
TC211	Technical Committee 211
UML	Unified Modelling Language
LLCRS	Libyan Land Cover Reference System
AICS	Italian Agency For Cooperation Development
UNGGIM	United Nations Committee Of Experts On Global Geospatial Information Management
SDGs	Sustainable Development Goals
AfDB	African Development Bank
NLCD	United States Geological Survey's National Land Cover Database
GLCC	Global Land Cover Characterization

Executive summary

Land use is an essential component for many areas, from water management to agriculture, from the fight against desertification to that against climate change. Detection changes in land cover allows a better understanding of the state and dynamics of natural resources and, to a certain extent, of their use. However, the legends used to describe land cover often have many inconsistencies and this limits their use and the sustainability of land cover monitoring efforts. The establishment of a common land cover classification system is one of the solutions identified to ensure consistency between maps prepared by different organizations. Also, with the establishment of an international standard for the development of land cover classification systems (ISO 19144-2), it is possible to use a national reference system and derive legends from it of land use that are interoperable. This facilitates the use of the same card for different objectives, forestry or agricultural, as well as for the assessment of ecosystem functions, the assessment biodiversity, the carbon cycle and many others.

Many land cover maps have been established for Libya, but, as in most countries, the legends were developed for very specific purposes, they are not interoperable and their use for the evaluation of temporal changes is greatly limited. The Government can establish a national land cover classification system, which allows interoperability and an integration whether for local applications (for example that collected by the teams of field) and national.

The objective of this document is to present the land cover reference system for Libya. The main aim of this reference system is to provide a common framework so that experts and land cover communities can generate their own legend and classes depending on their objective in Libya. This land cover reference system is based on Land Cover Meta Language (LCML) - ISO based standards. The rules that characterize each node in LCML are controlled by a specific object-based rule that is fully documented and explained in the publication. This publication is the result of collaboration between the Food and Agriculture Organization of the United Nations (FAO), Ministry of Water Resources, Ministry of Agriculture and Livestock, Libyan Centre for Remote Sensing and Space Science and University of Tripoli.

1. Introduction

land cover classification is essential for natural resource management, environmental monitoring, disaster management, agriculture and forestry, and urban planning. It enables the understanding of the distribution and extent of different types of vegetation, soil, water, and other natural resources (Di Gregorio and Jansen, 2016). This information is crucial for managing and conserving natural resources, sustainable land use planning and decision-making, emergency response, risk assessment, and disaster recovery planning. Unfortunately, the use of the different land cover maps and their integration into one functional system is limited by several constraints. Some of them such as lack of documentation, inconsistency in spatial and temporal resolutions, accessibility, lack of standardization. Others, mainly related to the semantic interoperability of different datasets as the result of the use of different classification systems, are often underestimated. However, these play a decisive and important role in the correct use and understanding of such information. Different land cover classification systems use different classification schemes and terminology, making it difficult to compare data across different regions or time periods. This can lead to confusion and errors in analysis and decision-making (Gregorio, 2016).

There are several land cover classification systems in use around the world. The most widely used classification systems include the Land Cover Classification System (LCCS), the United States Geological Survey's National Land Cover Database (NLCD), the European Environment Agency's CORINE land cover, the Global Land Cover Characterization (GLCC), and the World Wildlife Fund's Terrestrial Ecoregions. The LCCS is a standardized system developed by the Food and Agriculture Organization of the United Nations (FAO) (Di Gregorio, A., and Jansen, 2000; Di Gregorio, 2016; Gregorio and Jansen, 2005; Di Gregorio and Jansen, 2016; Jalal *et al.*, 2019). It classifies land cover into five broad categories: water bodies, forests, grasslands, croplands, and artificial surfaces and serval subcategories based on regional ecosystem. The NLCD is a classification system used in the United States, which classifies land cover into 21 classes. The CORINE land cover, is a classification system used in Europe, which classifies land cover into 44 classes. The GLCC is a classification system used at the global level, which classifies land cover into 24 classes. The Terrestrial Ecoregions classification system is used to describe global biodiversity patterns and classifies land cover into 825 ecoregions.

The Land Cover Classification System (LCCS/LCML) is a classification system used to categorize the different types of land cover on the Earth's surface. It is used to create land cover maps, which are important for understanding and managing natural resources, as well as for monitoring changes in land use and land cover over time.

The LCCS consists of a hierarchical structure of land cover classes, which are organized into different levels of detail. At the highest level, there are five major land cover categories: water bodies, forests, grasslands, croplands, and artificial surfaces. Each major category is further subdivided into more specific classes, such as broadleaf forests, coniferous forests, or mixed forests under the forests category.

The LCCS has been developed by the Food and Agriculture Organization of the United Nations (FAO and is widely used by many organizations and institutions involved in environmental monitoring and management. The system has evolved over time to reflect advances in remote sensing technology and changes in land use patterns. The latest version of the LCCS is the FAO's Global Land Cover Classification System (GLCCS), which was released in 2020 and includes 23 land cover classes at the highest level (FAO, 2021).

The Libyan land cover reference system is an effort to harmonize land cover monitoring in the country. The objective of this document is to present a national land cover reference system (LCRS) for representing LCLU. This document will serve as the basis for the development of national land cover maps, but also can be used as a reference for various national initiatives such as the national forest inventory or the greenhouse gas inventory and other activities that require information about regional, national, and subnational Land Cover and Land Use (LCLU) (Di Gregorio, 2016).

2. The Land Cover Meta Language (LCML)

2.1. Object-based representation of land information

Object-based representation of land information is a method of analysing and interpreting geospatial data that is based on the identification and analysis of objects within an image or map. This approach differs from traditional pixel-based methods of analysis, which focus on analysing individual pixels or groups of pixels within an image. In an object-based approach, the focus is on identifying and analysing objects within an image, such as buildings, trees, water bodies, or agricultural fields. This is done by grouping pixels that belong to the same object, based on characteristics such as spectral properties, shape, texture, and context (Di Gregorio, 2016). These groups of pixels are then classified as objects, and each object is assigned a set of attributes and properties, such as size, shape, orientation, and spectral signature.

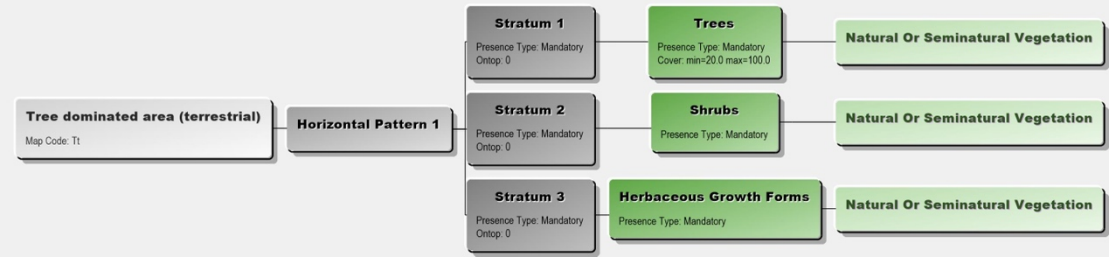
The main advantage of an object-based approach is that it allows for more accurate and detailed analysis of land information, compared to pixel-based methods. This is because objects within an image often have more distinct and consistent spectral and spatial characteristics than individual pixels. By analysing objects, it is possible to capture more detailed information about land cover and land use patterns, including the spatial arrangement of different features and the context in which they occur.

2.2. Land Cover Meta Language (LCML)

Land Cover Meta Language (LCML) is a standardized language used for describing and organizing information about land cover types and land use practices. It is designed to facilitate the sharing and integration of land cover data across different platforms and systems, and to improve the accuracy and consistency of land cover classification. LCML provides a standardized set of terms and definitions for describing land cover types, which can be used to create consistent and interoperable land cover maps. It also includes a set of rules and guidelines for data collection and classification, which can help to ensure that the data are accurate and reliable. LCML is based on a hierarchical structure, with general land cover categories at the top level (e.g. forest, grassland, wetland), and more specific subcategories at lower levels (e.g. deciduous forest, shrubland, marsh). This hierarchical structure allows for greater flexibility and granularity in land cover classification, while still maintaining consistency and interoperability. LCML is maintained by the European Environment Agency (EEA), which has developed a standardized LCML schema that can be used to represent land cover data in a consistent and interoperable manner. The schema includes a set of standardized codes and definitions for different land cover types, as well as guidelines for data collection and quality control (Di Gregorio and Jansen, 2016).

The FAO submitted the idea to the technical committee on geographic information ISO 211 in 2003 as a contribution to the creation of an international standard for land cover classification systems after decades of work mapping vegetation and land cover and many years of testing the LCCS (Land Cover Classification System) software. By Two standards were subsequently created. The first is a broad standard for dealing with classification systems. (ISO 19144-1 Classification Systems) The second is a rule for dealing with land cover. (ISO 1914-2 land cover meta language). In 2012, both standards were given ISO approval. The ISO 19144-1 and 19144-2 standards underwent a review procedure in 2018 and were re-approved. This occurs every five years. Parallel to the adoption of a new land use standard, FAO has suggested revising standard 19144-2 (LCML). (19144-3). FAO has created a tool to implement the ideas and regulations of the ISO LCML standard in order to make the standards' use easier. (LCCSv3 software). Its use is supported by the "LCCS tool" application, which exports legends in XSD format so they can be properly visualized and utilized in other systems or sophisticated analyses. Users have the freedom to create compatible representation systems and legends by using LCML/LCCS tools (Di Gregorio, A., and Jansen, 2000). The LCML was developed to characterize geographical entities for which the coverage terrestrial is described using a dictionary composed of atomic elements simple, predefined and standardized. Such elements (e.g. tree, shrub, grass, building, etc.) can be recombined in different ways to represent the different types of occupation of the floor. land cover is then represented in a database by a combination of basic elements or objects, which are characterized with their properties. The elements, their relationships, their properties and the characteristics associated with them are represented in a diagram (based on Unified Modelling Language (UML)). Also, the use of LCML makes it possible to have a description sufficiently detailed to enable comparisons to be made between the different classes and legends, whether local, national, regional or global, including for field observations, as long as they are described using the same method. This concept makes it possible to generate a database land cover data which is dynamic. This approach also allows users to use a limited number of classes if they wish. Moreover, in this approach, the characteristics of each class are represented by a model, in addition to a conventional name (1), for better understanding and readability (Yang *et al.*, 2017).

Figure 1 Description of a land cover class for a tree-dominated area



Source: Authors' own elaboration.

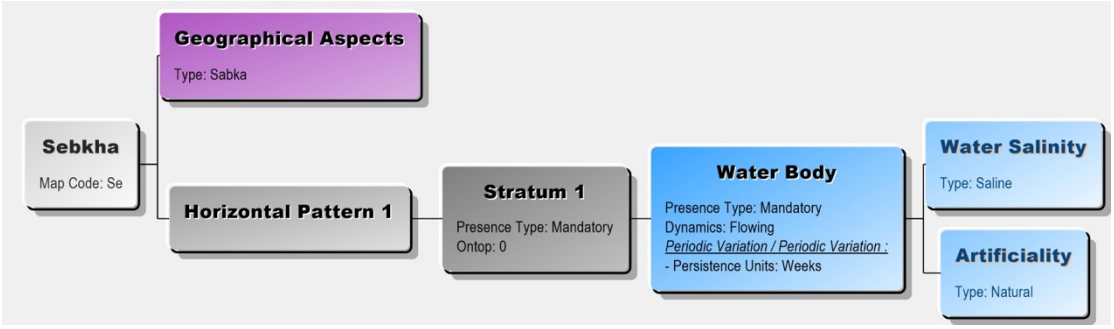
The implications of this process are fully synergistic with the progress of science in modern data management and still with a further possibility of improvements not yet fully exploited. Its intrinsic structure of an open object-oriented system allows not only an unambiguous description of real-world features, more consistent with the logic and structure of modern databases but also enlarges the capability of the system to describe phenomena related to inputs and activities people undertake on a certain land cover feature typical of agriculture and other land uses.

As not all the users are conversant with the UML, and it is also not functional to manually create an UML model for each land feature to be represented in a database. However, the whole concept is supported by a specific software produced by FAO. Land Cover Classification System version 3 (LCCS3) is, therefore, a tool to apply the concepts and rules of the ISO standard LCML. Its use is fast and intuitive, supported by adequate documentation (Di Gregorio, A., 2016a). In addition, it has the capability to be linked with another specific application software called LCCS tool with which the results of the legend generation can be exported in a markup language the XSD format that can be converted into a proper UML schema or ingested into a system for advanced queries of the derived database. In contrast to conventional methods, the LCML or LCCS is an ergonomic, dynamic method that provides the adequate management of the geographic data. Users can make choices, define, or update data description according to their needs and purpose (Di Gregorio, A., and Jansen, 2000; Owers *et al.*, 2021).

2.3. Importance of the system in the national context

The establishment of a "national land cover reference system" is a crucial step for establishing the basis for a constructive land use monitoring process for many applications. Indeed, as mentioned in the third section, often the legends national institutions are not the result of a joint effort between national institutions. This affects sharing information, quality of results, efficiency and sustainability of the process. Also, international standards (such as ISO/FAO LCML) contribute to the harmonization of systems national classification systems and to solve the problems mentioned above (Gregorio, 2016; Kosmidou *et al.*, 2014). However, the generation of a national legend remains a local activity which must be placed in the national context. A national land cover reference system can be the guideline, through which different national institutions derive specific legends for different applications (Figure 2). Structured in a complete list of the characteristics of the terrain, this repository is represented under graphic form for a better understanding of its relationship with the different legends existing. This national system aims to represent a complete, distinct and unambiguous order based on the elements that characterize the terrestrial environment (Figure 3). Also, various activities of cartography can refer to this representation system to create specific legends, according to the number and detail of the classes, while ensuring both the harmonization and the interoperability of all (Alawamy *et al.*, 2020, 2022; Al-Bukhari, Hallett and Brewer, 2018; Belhaj and Mubako, 2020; Li *et al.*, 2021).

Figure 2. An example of representation of Sabkha at different levels that define the meta-classes of the system

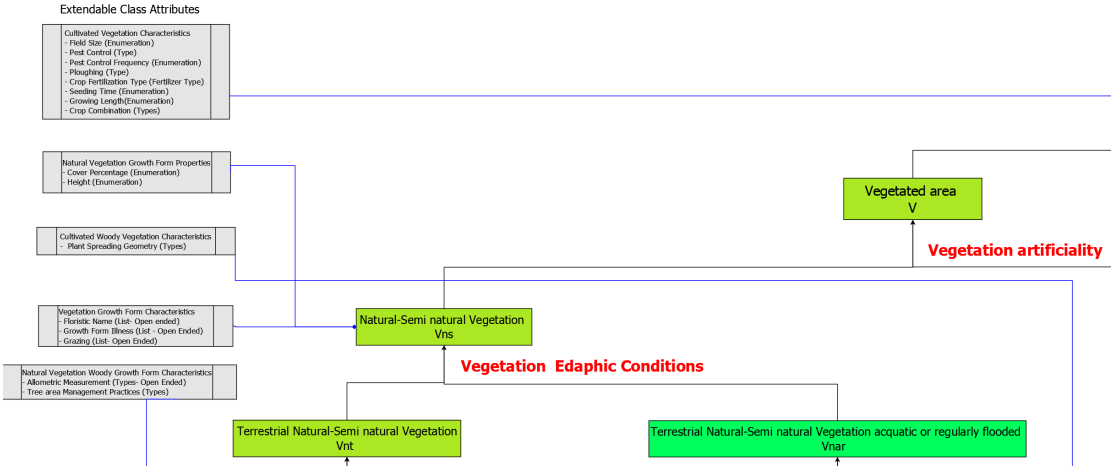


Source: Authors' own elaboration.

2.4. Features of schema diagram

The entire logic of the system is based on an "object" approach according to the ISO FAO LCML. A set of basic objects or elements is made available by the software LCCS3. These elements act as standardized building blocks and can be combined to describe more complex semantics for each class. Each class is represented in a modelling language (UML) which makes it easier and more precise to describe classes, meta-classes, elements and their characteristics (attributes) and allows an understanding their ontology and their use in a more efficient GIS modelling environment (Di Gregorio, 2016). They can be organized by layers and be enriched with attributes. These attributes are represented by grey blue boxes for which the link with the meta-classes are graphically documented (Figure 3).

Figure 3 Description Examples of features or attributes (blue boxes) used to characterize land cover classes and system content



Source: Authors' own elaboration.

Subsequently, the creation of a land cover legend, including the selection of classes and thus, their extension with additional attributes, is simple. A user can load the system from reference in the LCCS v3 software, possibly enriching the content of the class

with the characteristics ("attributes") desired (all listed in the LCCS v3 software) and create a code for the newly created class (by adding a symbol to the already existing code for example). THE reference scheme is composed of three components

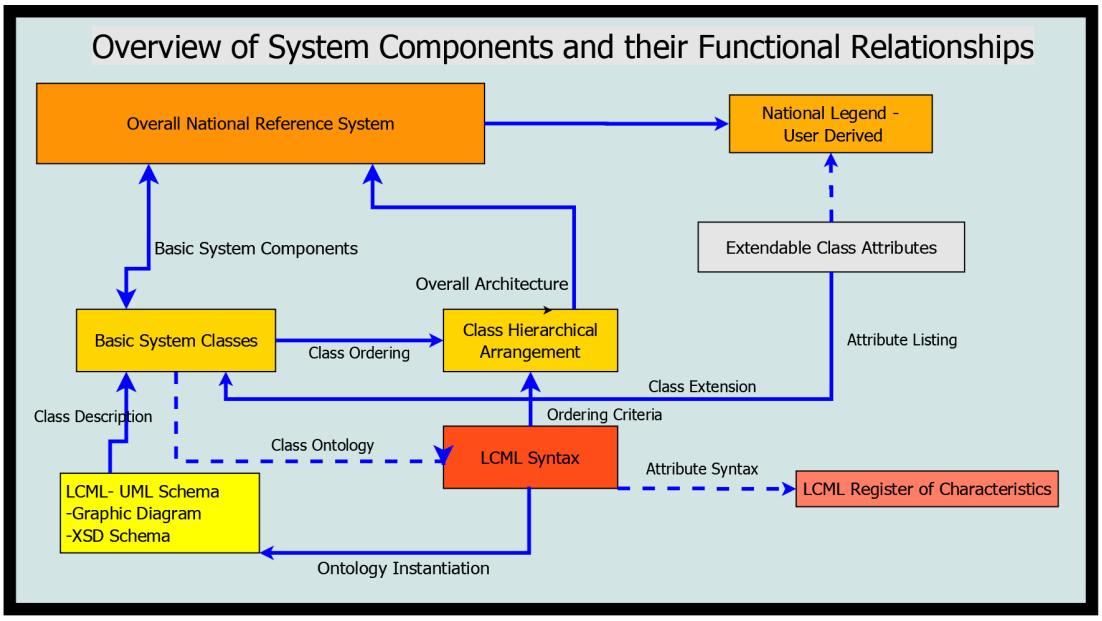
- The meta-classes which are distributed according to their level of characterization (framed with different colours).
- The rules that explain the difference between the classes at each level (text annotations in red).
- The attributes that allow a more detailed characterization of each class (blue boxes).

The reference diagram is represented by a diagram for a better understanding by the users. Some graphical symbols have been derived from UML (Unified Modelling Language) as follows: inheritance (black arrow), aggregation (solid diamond). The rules that characterize each "node" explain the conditions relating to the presence, absence and/or relevance of the objects and attributes.

2.5. National Reference System meta-class arrangement rules for Libya

- The model was created using a flowchart. Some Unified Modelling Language (UML) rules have been used e.g. The diagram is not a legend itself, but rather a graphical reference of how land cover features are organized and logically ordered in a specific geographical context.
- The definition and the order of the characteristics strictly follow the "Object Oriented" approach "Parametric" as specified in the international standard ISO 1914-4 Land Cover Meta Language (LCML).

Figure 4 Description Overview of the components of the land cover reference system and their functional relationships.



Source: Authors' own elaboration.

- The classes represented in the boxes are actually meta-classes. They represent the basic structure of specific land cover characteristics which can be further extended with additional attributes using the LCML.
- “Shared Dictionary of Terms and Attributes”. The coloured boxes represent the Meta-Classes and those in grey the additional attributes.
- Each node in the diagram and the subsequent subdivision is governed by a specific rule that is fully listed and documented.
- Each Meta-Class displayed in the lower level of the diagram is defined according to the ISO 19144-2 Land Cover Meta Language (LCML) approach using the LCCSv3 software.
- To create a legend, there is no restriction on the level of meta-classes to choose. For example, one can choose a very generic level for characteristic A and a very detailed level for characteristic B.

3. Land cover in Libya

Libya is a country that stretches along the northeast coast of Africa. Neighbouring countries include Tunisia and Algeria to the west; Egypt to the east; the Sudan, Chad and the Niger to the south. A greater part of the country lies within the "Sahara" (the Great Desert), while arable plateau land covers the part along the Mediterranean coast and farther inland. The land cover in Libya is characterized by a diverse range of ecosystems and habitats, including deserts, coastal zones, wetlands, and mountainous areas. The dominant land cover type in Libya is desert, which covers more than 90 percent of the country's land area. Within the desert regions, the most common land cover types are sand dunes, gravel plains, and rocky outcrops. There are also a number of oases and salt pans scattered throughout the desert regions, which provide important habitats for wildlife and support human settlements and agricultural activities. Along the Mediterranean coast, there are a variety of coastal ecosystems, including sandy beaches, rocky shores, and coastal wetlands. These areas provide important habitats for a variety of plant and animal species and support important economic activities such as fishing and tourism.

In the mountainous areas of Libya, there are a variety of different ecosystems, including forests, shrublands, and grasslands. These areas provide important habitat for a variety of wildlife species, including several rare and endangered species such as the Barbary macaque and the Mediterranean monk seal. In recent years, the land cover in Libya has been affected by a range of human activities, including urbanization, agricultural expansion, and oil and gas exploration. These activities have led to habitat loss and fragmentation, soil erosion, and other environmental impacts, which have the potential to affect the long-term health and sustainability of the country's ecosystems and natural resources.

3.1. National Reference System

The creation of a land cover national reference system for a country is usually underestimated. In many cases, different national legends in use are derived from the work of a single national institution that has not considered the development of a common reference system as a real national priority. Direct consequences of this situation are:

- land cover information are very difficult to exchange
- Efficiency of land cover databases are reduced;
- Information of land cover are very difficult to update;
- Human and financial resources are inadequately used.

The availability of international standards (as FAO LCML) is an important step to moving forward to a common syntax for the rationalization and harmonization of national classification systems. The land cover national reference classification system can be considered a general guideline and can be a very good tool to be used by different

national institutions to derive specific legends enabling them to improve the representation of specific applications.

The land cover national referenced system standardises the process of creating the classes and provides a general framework of rules that can be used to create specific legends. This reference system is represented in a graphical format for a better and easier understanding of the relationship and inheritance level of the different categories. The system aims to represent a comprehensive, distinct, and unambiguous ordering of the land features of a specific geographic area according to a specific object-based point of view.

Therefore, the development of this system comes in a crucial time to unite the way land cover legend is derived which will be of great importance in sustainable development. In addition, it harmonizes land cover monitoring in the country.

3.2. The status of land cover in Libya

There are several land cover maps available for Libya, which provide information about the country's land cover types and their distribution across the landscape (Alawamy et al., 2020, 2022; Al-Bukhari, Hallett and Brewer, 2018; Belhaj and Mubako, 2020; Li et al., 2021). Some of the most commonly used land cover maps for Libya includes land cover map of Libya 2009: This is a land cover map produced by the FAO, which provides information on land cover types at a spatial resolution of 30 metres. The Libya land cover dataset has been carried out with a visual interpretation of satellite images covering the period (2001-2002). The 108 original land cover classes have been clustered into 10 generalized classes (FAO, 2009). GlobCover 2009: This is a global land cover map produced by the European Space Agency, which provides information on land cover types at a spatial resolution of 300 metres. The map classifies Libya's land cover into categories such as croplands, forests, shrublands, wetlands, and artificial surfaces. MODIS land cover Type Yearly L3 Global 500m: This is a land cover map produced by the Moderate Resolution Imaging Spectroradio metre (MODIS), which provides information on land cover types at a spatial resolution of 500 metres. The map classifies Libya's land cover into categories such as forests, croplands, grasslands, and wetlands. CORINE land cover 2006: This is a land cover map produced by the European Environment Agency, which provides information on land cover types at a spatial resolution of 100 metres. The map classifies Libya's land cover into categories such as forests, shrublands, wetlands, and urban areas.

3.3. Institutional arrangements

Several government and non-government organizations focus on various environmental concerns and build databases to meet their project aims. However, because there is no common approach for assessing the physical properties of land cover, the databases remain inconsistent and cannot be combined with other information.

Historically, land cover systems and databases are the tasks assigned to the Agricultural Ministry in the country (This was the case in terms of the development of land cover legend of 2006). However, the development of the legend was a collective effort from different government agencies and centres such as the General Water Authority (WAG), Libyan Centre for Remote Sensing and Space Science (LCRSSS) and Environmental General Authority (EGA)

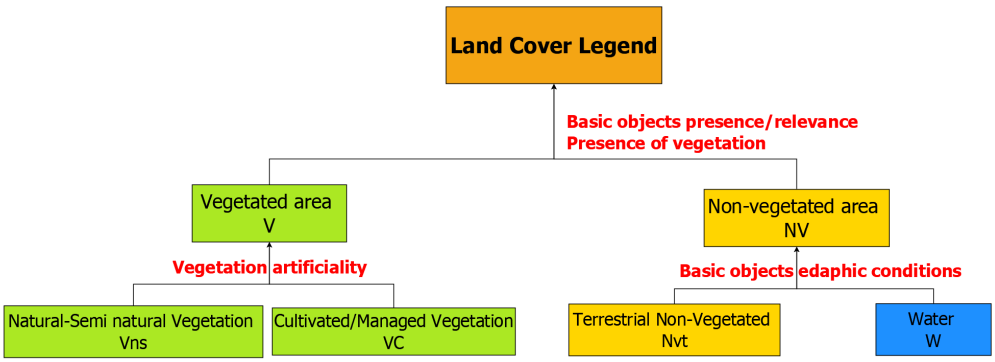
The Libyan land cover reference system is a collective effort between most of stakeholders in Libya. The Agriculture Ministry, Water Resources Ministry, National Meteorological Centre, Universities and NGOs.

FAO has provided the technical support in MerWat and IagWat projects to accomplish the achievement of Libyan land cover national reference system. A series of workshops, training, and discussion took place to achieve this system. This system can be used as a reference for various national initiatives such as the national forest inventory or the greenhouse gas inventory and other national activities that require information about national and sub-national land cover/use.

4. Rules for the meta-classes arrangement

To represent the variety of Libya land features, the land cover reference system is divided into different distinct levels. These levels have been created according to the number of details required to represent the overall land features of the region and are described according to the object-oriented rules and syntax of the LCML. In LCML land features are described/ordered according to a physiognomic/structural approach further refined with other qualitative attributes. The whole set of LCML elements and attributes are part of the LCML shared dictionary that guarantee a full interoperability and harmonization of the derived land features (FAO, 2021; Di Gregorio, 2016; Gregorio and Jansen, 2005). Each of these levels are defined according to specific rules that are fully listed and described below.

Figure 5. Separation of land features at basic level



Source: Authors' own elaboration.

4.1. First and second level

Main separation of the basic land features according to the following conditions:

- **Basic objects presence/absence:** the area is subdivided in two main groups vegetated surface and abiotic surface. The first group is defined by areas that have a vegetative cover of at least 4 percent for at least two months of the year. This cover may consist of woody life forms (trees, shrubs), Herbaceous life forms (for example, forbs, and graminoids) or a combination of them. On the contrary, any surface having < 4 percent of vegetated growth forms belong to the other group.
- **Vegetation artificiality:**

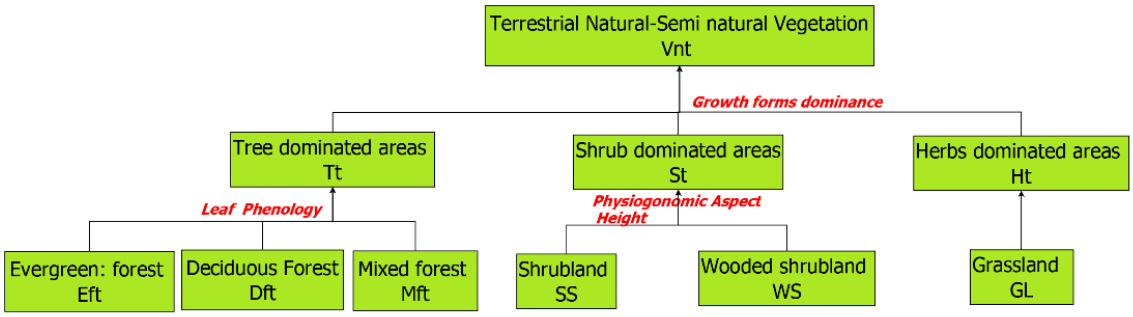
A natural vegetation is defined as an area where the vegetative cover is in balance with the abiotic and biotic forces of its biotope.

Semi-natural vegetation is defined as an area where the vegetation is not planted by humans but influenced by human actions. These may result from grazing, possibly overgrazing the natural phytocoenosis, or else from practices such as selective logging in a natural forest whereby the floristic composition has been changed. Previously cultivated areas that have been abandoned and where vegetation is regenerating are also included. The secondary vegetation developing during the fallow period of shifting cultivation is a further example. The human disturbance may be deliberate or inadvertent. Hence semi-natural vegetation includes 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.

B Cultivated and Managed Vegetation is defined as an area 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 an intent to harvest is included in this class (e.g. wheat fields, orchards, rubber, and teak plantations).

- **Basic objects (abiotic surfaces) edaphic conditions:** it refers to the presence/absence of water or other physical appearance of it. Water may not be present all year round.

Figure 6 Natural semi-natural vegetation



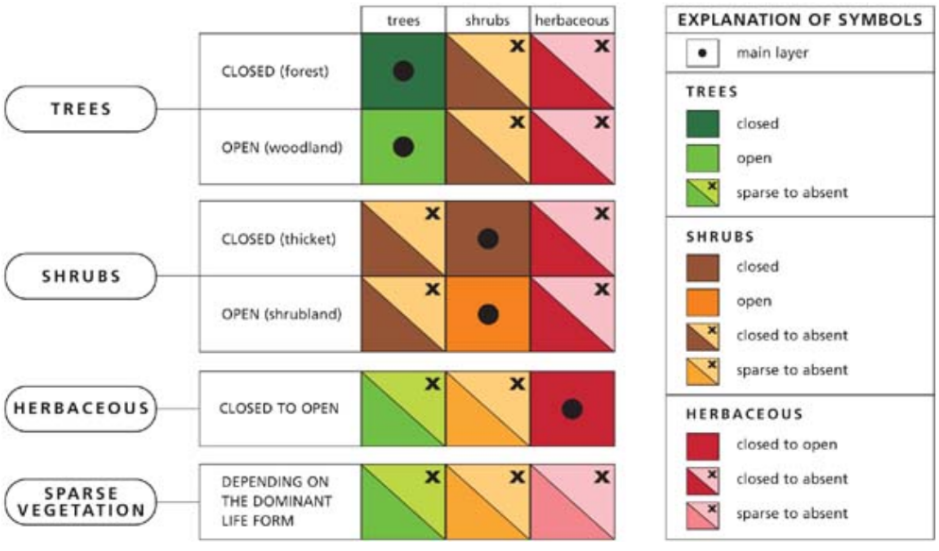
Source: Authors' own elaboration.

4.2. Natural semi-natural vegetation

Description of the rules governing the subdivision of the natural semi-natural vegetation terrestrial:

- **Natural semi-natural vegetation edaphic conditions:** it describes areas that are transitional between pure terrestrial and aquatic systems. In the second case the vegetative cover is influenced by the presence of permanent water, or the water table is usually at or near the surface or the land is covered by shallow water. The predominant natural vegetation, at least periodically, comprises hydrophytes. Marshes, swamps, bogs or flats where drastic fluctuations in water level or high concentration of salts may prevent the growth of hydrophytes are all part of this class. Occasionally flooded vegetation within a terrestrial environment is not included in this class.
- **Growth forms dominance:** it defines the main domain that characterizes a specific vegetated area. Following the major structural vegetation classifications worldwide the main criterion is characterized by uppermost canopy layer logic. This means that the dominant layer goes from Woody Life Forms (tree/shrub or woody canopy) to herbaceous life form (forbs or graminoids).
- This general rule is subject to **a sub-condition of cover:** It is only valid if the dominant life form has a cover from 10 to 100 percent (closed to open). If the life form is < 10 percent (sparse), the dominance goes to another life form that has a closed or open cover (Figure 5-3).

Figure 7 Subdivision of the natural semi-natural vegetation terrestrial



Source: FAO. 2021. Register implementation for land cover legends. https://doi.org/10.4060/cb5130en

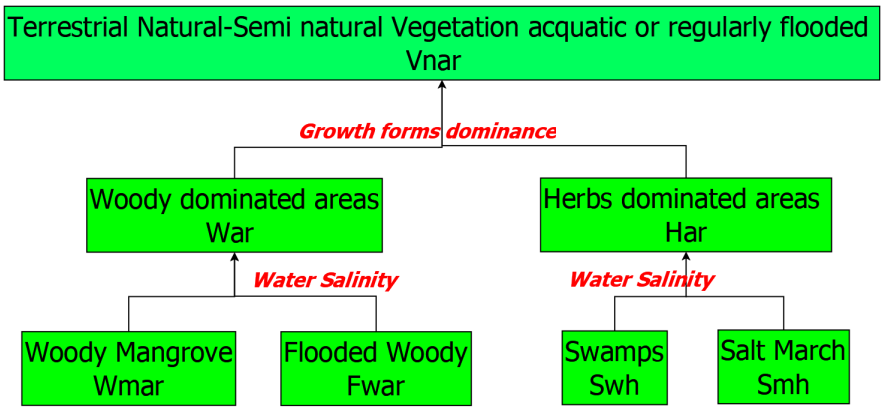
- **Tree cover percent:** the cover defines the proportion of a particular area of the ground, substrate or water surface covered by a layer of plants, considered at the greatest horizontal peri metre level of each plant in the layer.
- **Physiognomic aspect height:** it defines the height of a layer of a growth form expressed in metres. The height of a certain layer is measured from the ground to the average top of the life form being assessed. The fact that single plants of one synusia differ from the average height can be ignored, apart from the fact that they can form their own layer (strata).
- **Growth forms cover percent and height:** it refers to the cover percent and height of the herbaceous growth forms (see the definitions above).
- **Tree layering and geographic location:** layering or stratification refers to the vertical disposition of a certain life form. The geographic location (in this case altitude expressed in metres above sea level) refers to the general location of a certain feature.
- **Shrub cover percent:** see above.
- **Horizontal pattern disposition:** it defines the macro pattern of vegetation formations, defined as the horizontal spatial distribution of vegetation in a certain area. It should not be confused with Cover, which defines the spatial arrangement of life forms (e.g. trees and shrubs). A horizontal pattern may be used for a complex LC class composed by two or more distinct LC features that will be handled as a unicum independently from scale constraints
- **Growth forms layer presence/absence:** it defines the presence/absence of different growth forms strata.

4.3. Natural semi-natural aquatic or regularly flooded vegetation

Description of the rules governing the subdivision of the natural semi-natural aquatic or regularly flooded vegetation are as follows:

- **Growth forms dominance:** see above
- **Water salinity:** it refers to the concentration of Total Dissolved Solids (TDS), expressed as part for millions in the water.
- **Water persistence:** it refers to the length on which the water remains in a specific area.

Figure 8 Natural semi-natural aquatic vegetation



Source: Authors' own elaboration.

4.4. Cultivated and managed vegetation

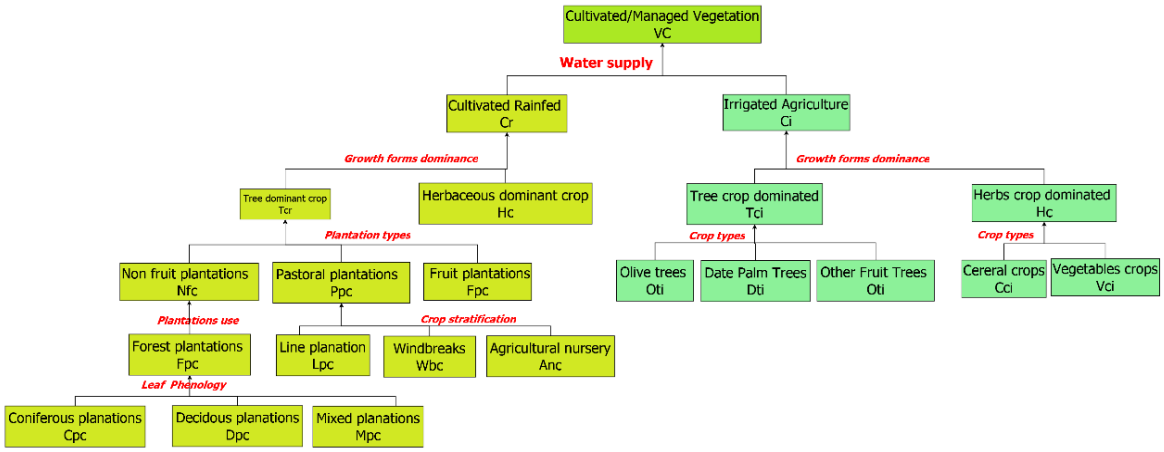
Description of the rules governing the cultivated and managed vegetation.

- **Water supply:** it refers to the main watering regime of a specific crop if it relies on rainfall or on artificial.
- **Growth form dominance:** see above definition.
- **Waterbody persistence:** it refers to the presence and duration of water supply for the growing of a specific crop.
- **Plantation types:** it refers to distinction made between forest plantations (plantation of woody plants done for timber or other type of purposes that imply the harvest of the plant after a certain number of years) and orchards and other types of plantations (plantation of woody plants done for the regular harvest of fruits or other goods. The plants are permanent).
- **Plant stratification:** it refers to the presence/absence of one or more additional layers of growth forms in addition to the main one.
- **Crop cultivation period:** it refers to the length on which a land is covered by crops i n the growing season.
- **Cropping intensity:** it refers to the amount of harvests of annual crop (s) within one year.
- **Leaf phenology:** it refers to the general behaviour of woody plants throughout the year. A distinction is made between:

  Evergreen: perennial plants that are never entirely without green foliage.

Deciduous: perennial plants that are leafless for a certain period during the year. Leaf shedding usually takes place simultaneously and in connection with the unfavourable season.

Figure 9. Cultivated and managed vegetation



Source: Authors' own elaboration.

- **Crop stratification:** it refers to the simultaneous presence/absence of two or more layers of crops.
- **Crops occurrence:** it refers to the presence/absence of a crop during the yearly cultivation period.
- **Evergreen:** perennial plants that are never entirely without green foliage (Ford-Robertson, 1971).
- **Horizontal pattern disposition:** it refers to the spatial combination of different land features that form a unicum. See above definition.

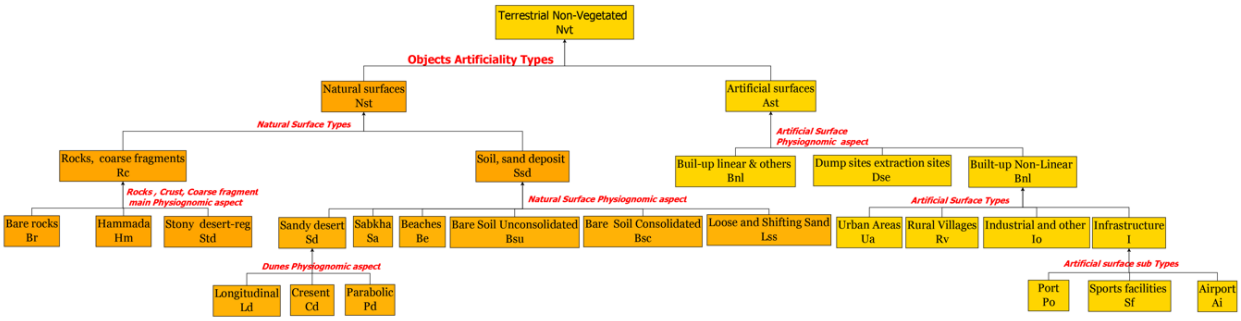
4.5. Terrestrial non-vegetated and water and associated areas

Description of the rules governing the terrestrial non-vegetated and water and associated areas are as follows:

- **Abiotic surfaces aspect (artificiality):** natural bare areas are distinguished from artificial surfaces because in the second case the area is mainly covered by an artificial surface resulting from human activities.

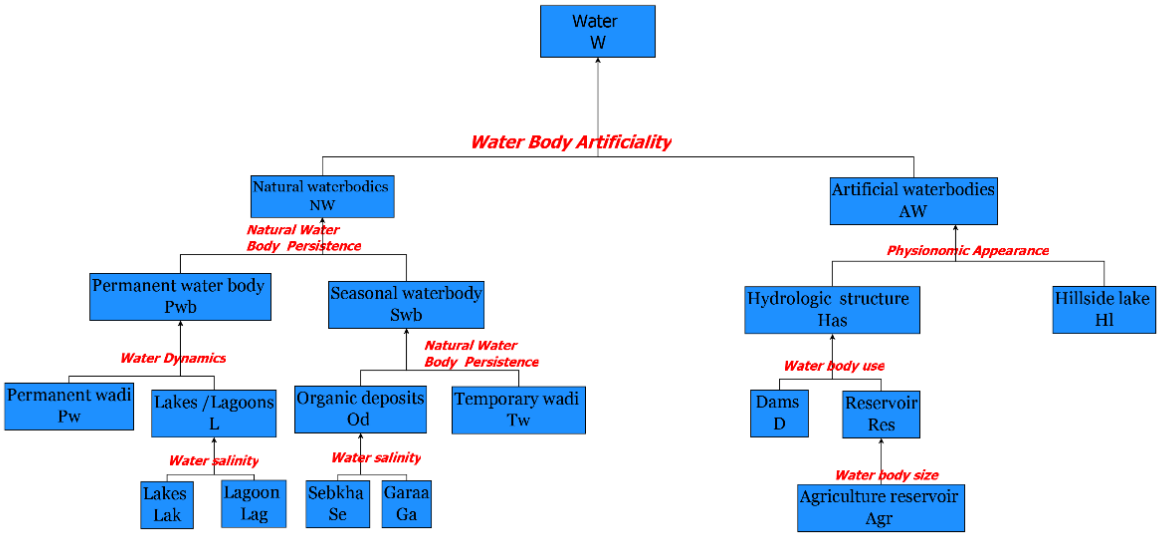
- **Waterbody artificiality:** refers to two major differentiation of the water bodies, natural and artificial where the second one is defined as an area where under natural circumstances, no water surface would exist. Therefore, these surfaces are the result of an artefact, such as the construction of a dam, artificial snow, or ice.

Figure 10 Terrestrial non-vegetated and associated areas



Source: Authors' own elaboration.

Figure 11 Water and associated areas

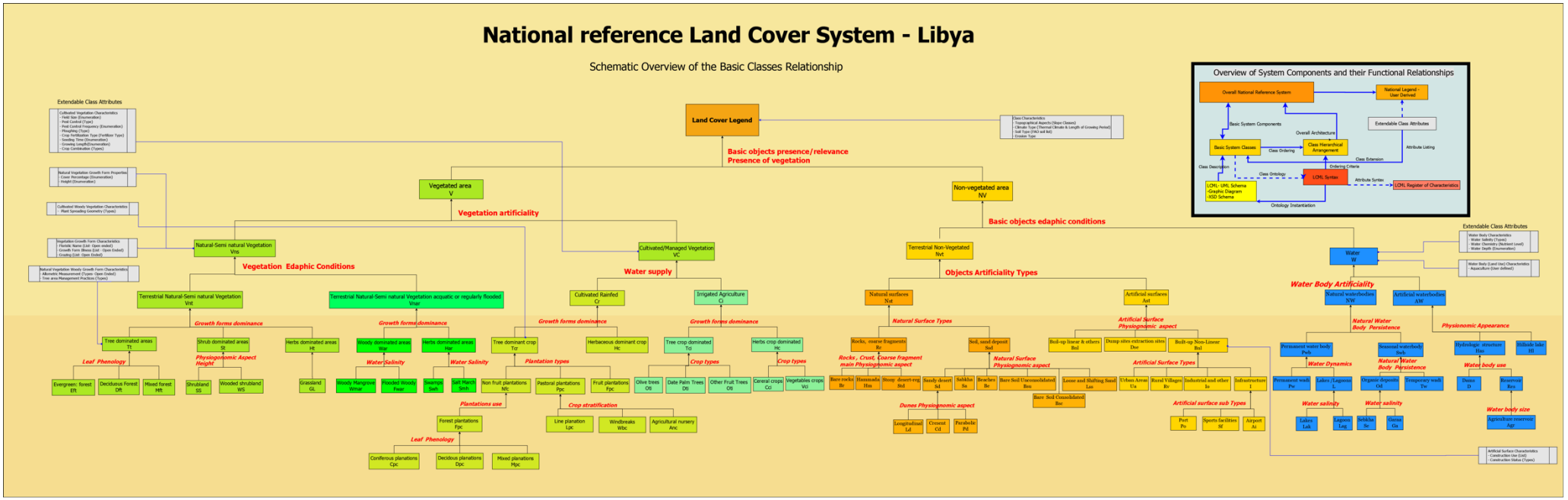


Source: Authors' own elaboration.

- **Rocks, coarse fragments:** It corresponds to areas with natural surfaces where the rocky and coarse fragments are dominant. The presence of sub-surfaces is recognized with main physiognomic aspect.
- **Bare rocks:** It corresponds to areas with natural surfaces where bare rocks are dominant.
- **Hamada:** a rock-floored or rock-strewn desert region especially in the Sahara

- **Stony desert**: desert surface covered with closely packed, interlocking angular or rounded rock fragments of pebble and cobble size. It is also called desert pavement.
- **Soil, sand deposit**: Soil, Sand deposits represent naturally developed unconsolidated areas. The surface is usually covered with a natural deposition of sand or other soil paricles like silt or clay.
- **Sandy desert:** A broad, flat area of desert covered with wind-swept sand with little or no vegetative cover.
- **Longitudinal:** Longitudinal dunes elongate parallel to the prevailing wind direction, creating parallel ridges of dunes. These occur where the sand supply is neither high or low. Transverse dunes are perpendicular to the wind direction and occur where there is an abundant source of sand.
- **Crescent:** Crescent dunes are sand dunes with two "horns" that point away from the wind. These dunes are created by winds of different strengths that blow from the same direction and carry different amounts of sand. They can be 330ft
- **Parabolic:** parabolic dune are sand dunes forms when strong winds erode a section of the vegetated sand (commonly referred to as a blowout). It is also called U shape sand dunes.
- **Sabkha:** are flat and very saline areas of sand or silt lying just above the water-table and often containing soft nodules and enterolithic veins of gypsum or anhydrite.
- **Beaches:** A beach is a narrow strip of land separating a body of water from inland areas. Beaches are usually made of sand, tiny grains of rocks and minerals that have been worn down by constant pounding by wind and waves.
- **Bare soil unconsolidated**: A defined area is covered with materials that are neither solid nor firm. The surface can be penetrated with a spade or a hoe.
- **Bare soil consolidated** are characterized by the solid and firm consistency of their surface or by the presence of coarse fragments with these properties. The surface and the coarse materials remain coherent and hard even when moist.
- **Loose and shifting sand**: These areas are covered by soil particles. These particles may be moved by regularly occurring winds and form distinct patterns. A Stony surface can be specified.

5. The National reference land cover schema



Source: Authors' own elaboration.

The LCRS is based on 3 levels, these levels and their relationships are described in detail in chapter 5. The whole schema is divided into major categories i.e. vegetated (biotic) and non-vegetated (abiotic). The vegetated category is further categorized into natural and cultivated and non-vegetated into terrestrial non-vegetated and water. In the upper right corner of the schema, please see the national reference land cover scheme available at the link[1] concepts and their functional relationship can be seen while in the white boxes, attributes for class expansion can be seen. Complete class list with the description and photograph can be seen in appendix A. Detailed steps are available in appendix C for users to use this schema and create their own legend based on their requirements.

[1] land cover reference system - Libya full Schema

6. Using the land cover reference system

As specified in other parts of this document the land cover reference system is not a legend per se but more a systematic overview of the different LC aspects of the country represented and ordered according to an "Object Oriented" logic using the ISO standard 19144-2 LCML. Therefore, any user that wants to prepare its own legend has to follow a particular procedure. This section describes the different easy steps to be done. Those activities can be by (1) understanding the overall structure of the regional system and selection of the classes that will be part of the legend, and (2) using LCCS3 (Appendix C).

Step 1 – Understanding the overall structure of the system.

The schema is divided in different levels starting from the more general to the more detailed ones. In each level the land cover features are arranged in meta-groups. The built-up of each group and its position in the schema is regulated by specific rules that are clearly listed in the document (see section- 5 for details). It is important for the user to understand those rules because they give a clear picture of the reasons why some classes are grouped in a certain way and not the other.

Step 2 – Select the classes needed for a specific legend.

Looking at the general schema (link will be added) the user can select the classes with which he/she wants to populate his own legend. There are different levels from the more general to the more detailed one. The user is free to navigate inside the schema selecting for instance a class of vegetation at the very detailed level of the system and another one of agriculture at a more general level. The user must remember that those are meta-classes that can later be further eventually customized according to specific needs.

Step 3 – Understanding the meaning of each selected class.

When a set of classes have been selected, it is important that the user fully understand their meaning. This can be done looking in Appendix A to the full description of each class. The user will also find specific indications on how the meaning of those meta-classes can be further expanded.

Step 4 - Loading the LCCS national files

The whole classes represented in the graphical schema are built up and recorded in the FAO LCCS3 software. For the Libya system to make their use easier the classes have been grouped in 3 regional files. Reference file can be downloaded from FAO land cover legend registry (Mushtaq, F., *et.al* 2022).

Step 5 - Creation of the user defined legend

The user-defined legend can be created just by doing a copy-paste of the selected classes into a “New Legend” created in the LCCS3 software.

Step 6 - Further customization of the legend classes

When the specific user defined legend has been created, the user can act in each single class to add or refine specific class details. When an original meta-class is modified, to assure harmonization with any other legend derived from the same system it is important to maintain the original map code followed by an extra code symbol e.g. original map code for Steppe (meta class) is “St" and code for Steppes arborée et arbustives map code should be “St(aa)”. In this code “St” is the original code while “aa” is added for the expanded/new class (i.e. original meta-class code (new code) - > St(aa)).

7. Conclusion

This is the first land cover legend reference system for Libya. The Libyan land cover legend reference system represents the structural form that was developed as a system to describe the features most likely to be found in Libya, in collaboration with national institutions. The system attempts to instantiate all these basic requirements in an innovative logical framework adapted and refined for Libya. To better understand the concept of the system, it is important to analyse its structure and the functional relationship of the different elements. The definition of the classes used in the regional system is clear, precise, and based on objective criteria. These classes are "Meta classes" and can be extended if necessary.

The system is designed to be flexible enough to adapt and evolve with needs. In addition to creating specific legends for different applications, the system can also be used to make comparisons with other existing classifications. Furthermore, the land cover legend reference system for Libya offers promising potentials for integrating land cover monitoring and field data collection initiatives for one of the fundamental geospatial data themes.

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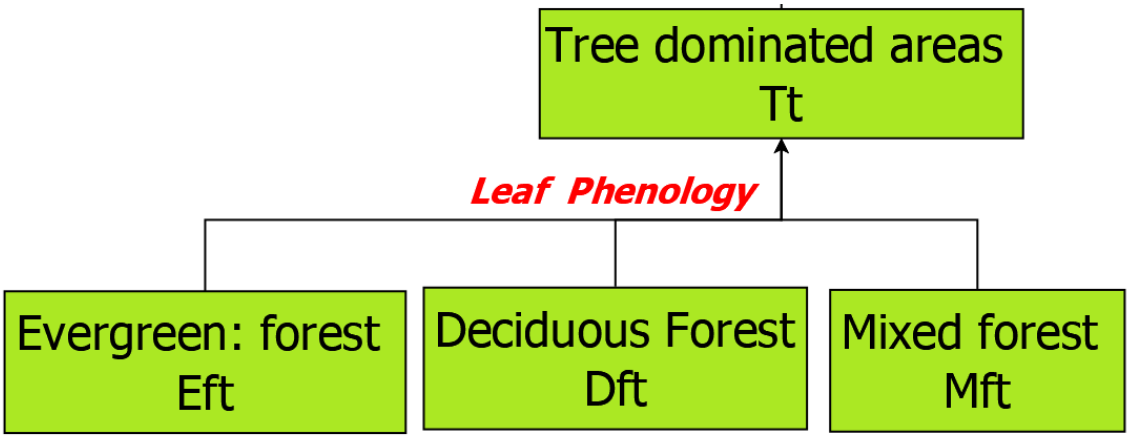
Appendix A - land cover groups and classes in Libya

Section I
Natural semi-natural vegetation (terrestrial) - Vnt

Tree dominated area – Tt

It corresponds to areas with natural semi-natural vegetation where the growth form tree is dominant. The cover percentage of the element tree is less than 20 percent that is cover ranging from 20 to 100 percent. The presence of other woody (shrubs) or non woody (herbs) growth forms is recognized with any cover percentage.

Figure A.1 Structure of tree dominated areas



Derived classes (first level)

Three derived classes are foreseen classified as closed tree formation and open tree formation (woodland), sub-divided according to the different cover ranges that characterize the dominant element tree.

Evergreen forest (Eft)

This refers to the phenology of perennial plants that are never entirely without green foliage.

Decidous forest description (Dft)

This class describes the generic aspect of a so-called dry forest. It is constituted by one mandatory stratum that defines the overall class structure. The strata is constituted by one basic element tree. The element tree has two attributes:

- Cover expressed in percent of plants covering the ground ranging from 70 to 100 percent.
- Height expressed in metres ranging from 5 to 30 metres.
- vegetation artificiality in this case defined as natural

A strata of basic element shrub with the following attributes:

- Cover expressed in metres ranging from 10 to 50 percent.
- Height expressed in metres ranging from 4 to 5 metres.
- Vegetation artificiality defined as natural.

Derived classes (second level)

A further sub-division is made both for the closed and open tree formation. At this level the classes have a detailed structural aspect. A further expansion of the thematic details can be done, if necessary, as listed in the class expansion section.

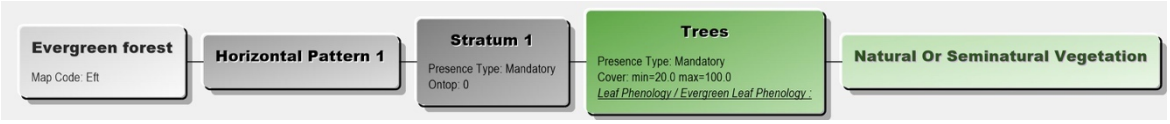
Evergreen forest - Eft

Picture

Description

This refers to the phenology of perennial plants that are never entirely without green foliage.

LCCS diagram



Deciduous forest - Dft

Picture

Description

This class describes the generic aspect of a so-called dry forest It is constituted by one mandatory stratum that defines the overall class structure. The strata is constituted by one basic element tree.

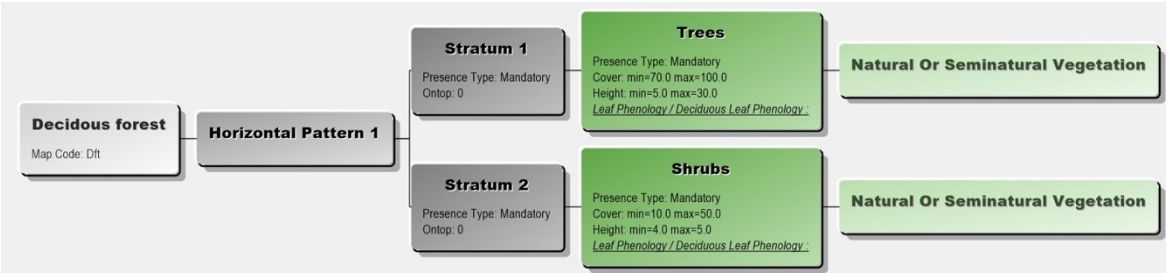
The element tree has two attributes:

- Cover expressed in percent of plants covering the ground ranging from 70 to 100 percent.
- Height expressed in metres ranging from 5 to 30 metres.
- vegetation artificiality in this case defined as natural

A strata of basic element shrub with the following attributes:

- Cover expressed in metres ranging from 10 to 50 percent.
- Height expressed in metres ranging from 4 to 5 metres.
- Vegetation artificiality defined as natural.

LCCS diagram



Mixed forest - Mft

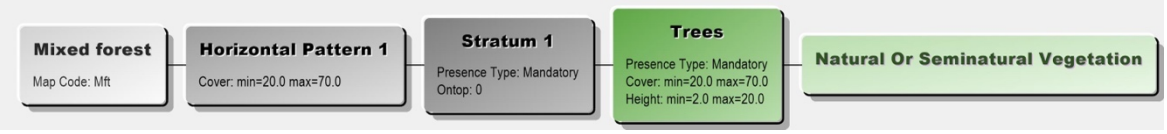
Picture

Description

This class describes the generic aspect of a so-called open woodland area. It is constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element tree. The element tree has two attributes:

- Cover expressed in percent ranging from 20 to 70 percent.
- Height expressed in metres ranging from 5 to 20 metres.
- Vegetation artificiality defined as natural.

LCCS diagram



Class expansion for tree dominated area

The regional reference schema gives to the user a wide possibility to enrich the thematic details of each class. This can be done using the shared dictionary of attributes of the ISO standard LCML. Following this process, each further enrichment of legend categories will assure a full harmonization process of different legends that for different reasons (legend scope, terrain knowledge etc.) wants to have different thematic attributes to define their classes. In this specific context, the foreseen suggested class thematic enrichment attributes could be the following:

Physiognomic structural properties:

- **Height:** more specific height can be used to better characterize the basic element tree.
- **Leaf phenology:** specific leaf phenology for each growth form can be defined.
- **Leaf type:** specific leaf type for each growth form can be added.
- **Adding different strata of growth forms:** in addition to the main stratas characterizing this class other strata with different growth, forms can be added.

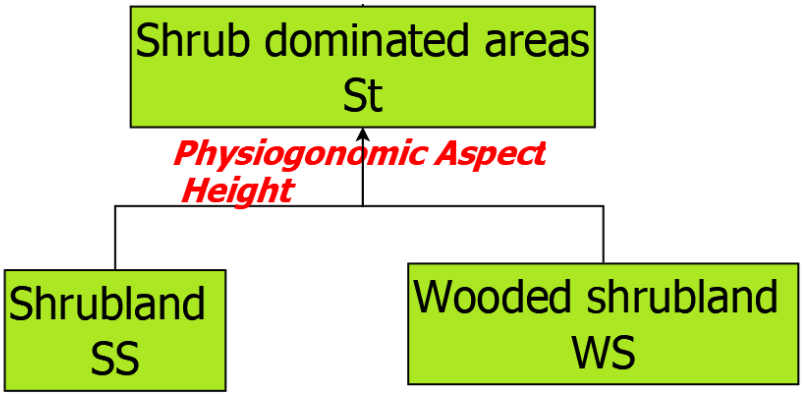
Other attributes:

- **Floristic name:** intended as the floristic name of the plant species.
- **Growth from illness:** intended as the percent of trees damaged and the ilness type.
- **Burnt status:** intended as the percent of trees burnt over the total.
- **Tree area management practices:** intended as types of forest management undertaken in a certain forest are.
- **Geographic location or altitude:** intended as any information related to a specific geographic location and or altitude ranges.
- **Any other attributes:** other attributes derived from the LCML shared dictionary.

Shrub dominated area - St

It corresponds to areas with natural semi-natural vegetation where the growth form shrub is dominant. The cover percentage of the element shrub is greater than 20 percent that is cover ranging from 20 to 100 percent. The presence of other woody (shrubs) or non woody (herbs) growth forms is recognized with any cover percentage.

Figure A.2 Structure of shrub dominated areas



Derived classes (first level)

Three derived classes are foreseen classified as shrubland (medium, high) and Wooded shrubland and Copse.

Shrubland (SS)

This class is constituted mainly by shrubs with a coverage of about 20 to 100 percent. Vegetation height varies between 2m and 5m.

Wooded Shrubland (WS)

This class is constituted mainly by shrubs with a coverage of about 20 to 100 percent. Vegetation height varies between 0.2m and 2m.

Shrubland - Ss

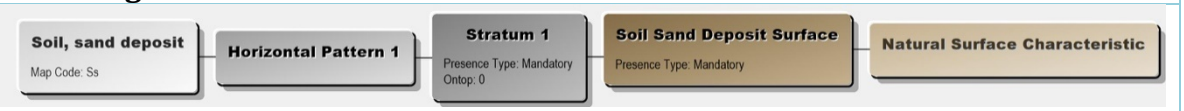
Picture

Description

This class describes the generic aspect of an open shrublands. It is constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element shrubs.

- Cover expressed in percent of plants covering the ground ranging from 20 to 70 percent.
- Height expressed in metres ranging from 2 to 5 metres.
- vegetation artificiality in this case defined as natural.

LCCS diagram



Wooded Shrubland - Ws

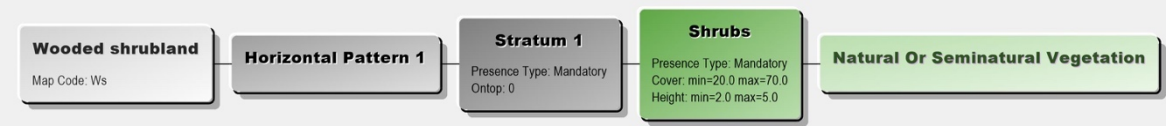
Picture

Description

This class describes the generic aspect of a thicket. It is constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element shrubs.

- Cover expressed in percent of plants covering the ground ranging from 70 to 100 percent.
- Height expressed in metres ranging from 2 to 5 metres.
- vegetation artificiality in this case defined as natural.

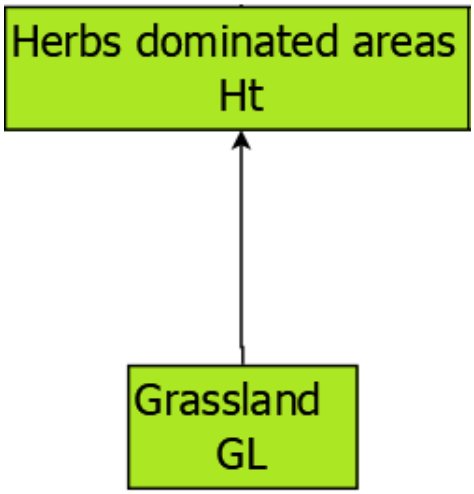
LCCS diagram



Herbs dominated area – Ht

This level corresponds to an area of natural vegetation with the mandatory presence of herbs. Herbaceous growth covers 20 – 100 percentage of the landscape. The structure of herbs dominated area is provided in Figure 14.

Figure 12. Structure of herbs dominated areas



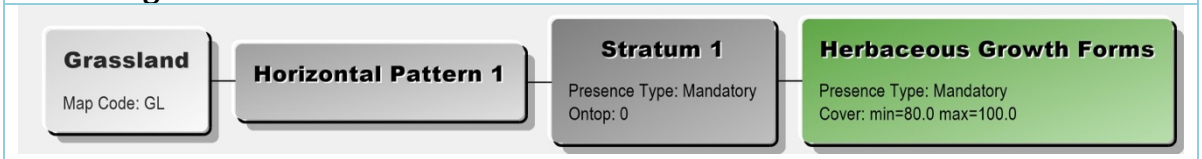
Grassland - GL

Picture

Description

Areas dominated by gramanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

LCCS diagram

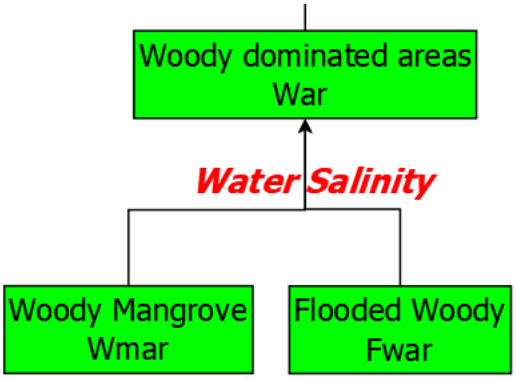


Section II
Natural semi-natural vegetation (aquatic or regularly flooded) - Vnar

Woody dominated area – War

It corresponds to areas with natural semi-natural vegetation where the growth form woody is dominant. The cover percent of the element woody is greater than 20 percent (>20 percent) that is cover ranging from 20 to 100 percent. The presence of non-vegetated area that is water body is recognized in this area.

Figure A.3 Structure of woody dominated areas



Derived classes (first level)

Two derived classes are foreseen classified as woody mangrove and flooded woody, sub-divided according to the different cover ranges that characterize the dominant element woody.

Woody mangrove (Mmar)

This class is very basic, and generic being constituted by two mandatory stratum that defines the overall class structure. The strata are constituted by two basic elements that is woody and water body. The element woody has two attributes:

- Cover expressed in percent of plant covering the ground ranging from 20 - 100 percent.
- Vegetation artificiality in this case is defined as natural vegetation.

The element water body has two attributes:

- Periodic type is tidal

- Artificiality of water body is natural.
- Water salinity is brackish.

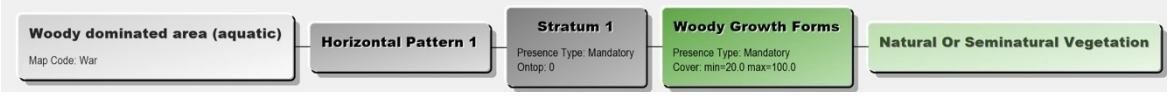
Woody dominated area – War

Picture

Description

It corresponds to areas with natural semi-natural vegetation where the growth form woody is dominant. The cover percent of the element woody is greater than 20 percent (>20 percent) that is cover ranging from 20 to 100 percent. The presence of non-vegetated area that is water body is recognized in this area.

LCCS diagram



Class expansion for woody dominated area

The regional reference schema gives to the user a wide possibility to enrich the thematic details of each class. This can be done using the shared dictionary of attributes of the ISO standard LCML. Following this process, each further enrichment of legend categories will assure a full harmonization process of different legends that for different reasons (legend scope, terrain knowledge etc.) wants to have different thematic attributes to define their classes. In this specific context, the foreseen suggested class thematic enrichment attributes could be the following:

Physiognomic structural properties:

- **Height:** more specific height can be used to better characterize the basic element tree.
- **Leaf phenology:** specific leaf phenology for each growth form can be defined.
- **Leaf type:** specific leaf type for each growth form can be added.
- **Adding different strata of growth forms:** in addition to the main stratas characterizing this class other strata with different growth, forms can be added.
- **Water body:** Water artificiality and salinity type can be further added.
- **Water periodic variation:** Period type and persistence period can be added.

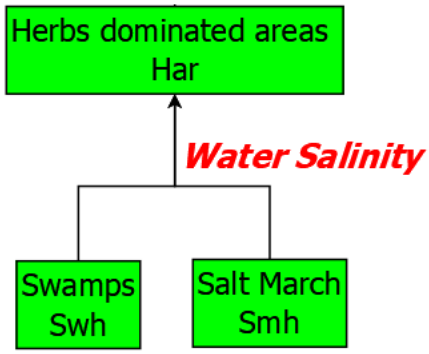
Other attributes:

- **Floristic name:** intended as the floristic name of the plant species.
- **Growth from illness:** intended as the percent of trees damaged and the illness type.
- **Tree area management practices:** intended as types of forest management undertaken in a certain forest are.
- **Geographic location or altitude:** intended as any information related to a specific geographic location and or altitude ranges.
- **Any other attributes:** other attributes derived from the LCML shared dictionary.

Herbs dominated area – Har

This level corresponds to an area of natural vegetation with the mandatory presence of herbs and water body. Herbaceous growth covers 20 – 100 percent of the landscape. The structure of herb dominated area can be seen in Figure 17.

Figure A.4 Structure of herbs dominated areas



Derived classes (first level)

Two derived classes are foreseen classified as swamps and salt marsh, sub-divided according to the different cover ranges that characterize the dominant element herbs and water body.

Swamps (Ahm)

This class is very basic, and generic being constituted by two mandatory stratum that defines the overall class structure that is herbaceous growth form and water body. The element herbs have two attributes:

- Cover expressed in percent of plant covering the ground ranging from 20 - 100 percent.
- Vegetation artificiality in this case is defined as natural vegetation.

The element water body has two attributes:

- Artificiality of water body is natural.
- Water salinity is fresh.

Salt marsh (Ahms)

This class is very basic, and generic being constituted by two mandatory stratum that defines the overall class structure that is herbaceous growth form and water body. The element herbs have two attributes:

- Cover expressed in percent of plant covering the ground ranging from 20 - 100 percent.
- Vegetation artificiality in this case is defined as natural vegetation.

The element water body has two attributes:

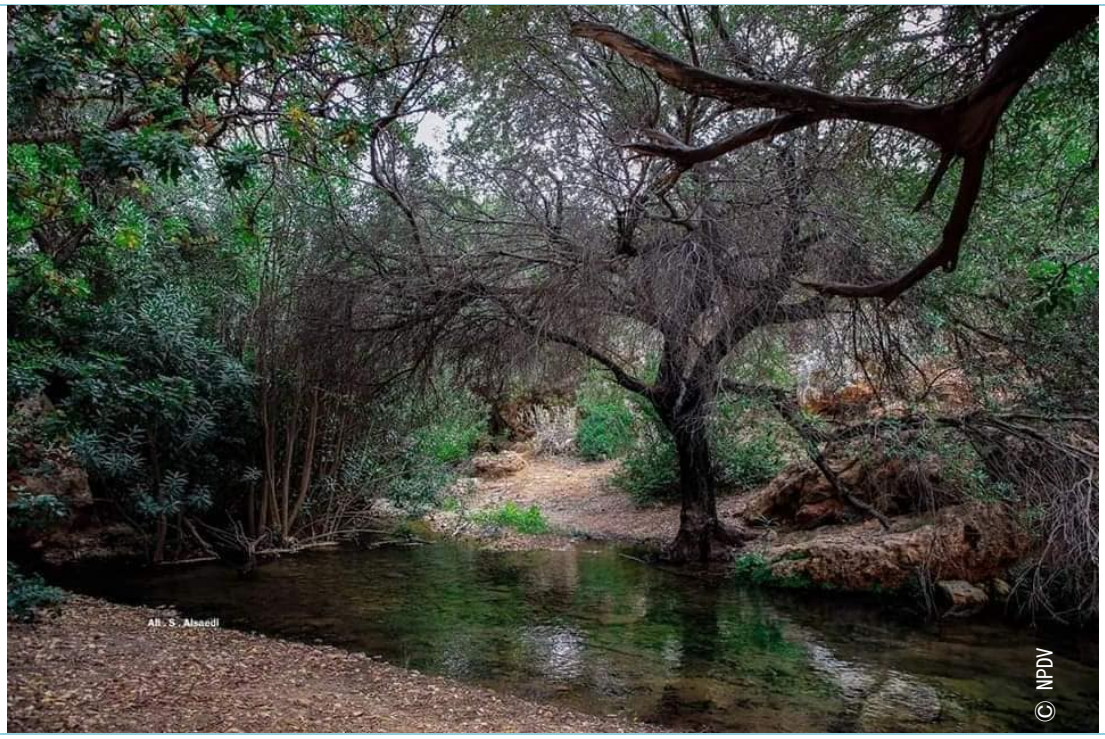
- Artificiality of water body is natural.
- Water salinity is brackish.

Derived classes (second level)

A further sub-division is made both for the closed and open tree formation. At this level the classes have a detailed structural aspect. A further expansion of the thematic details can be done, if necessary, as listed in the class expansion section.

Swamps -Swh

Picture



Description

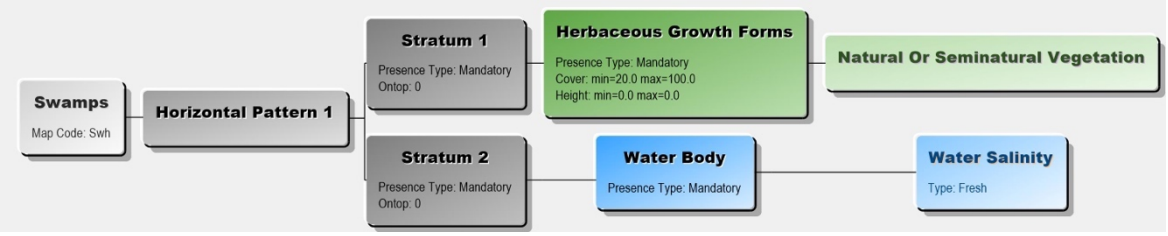
This class is very basic, and generic being constituted by two mandatory stratum that defines the overall class structure that is herbaceous growth form and water body. The element herbs have two attributes:

- Cover expressed in percent of plant covering the ground ranging from 20 - 100 percent.
- Vegetation artificiality in this case is defined as natural vegetation.

The element water body has two attributes:

- Artificiality of water body is natural.
- Water salinity is fresh

LCCS diagram



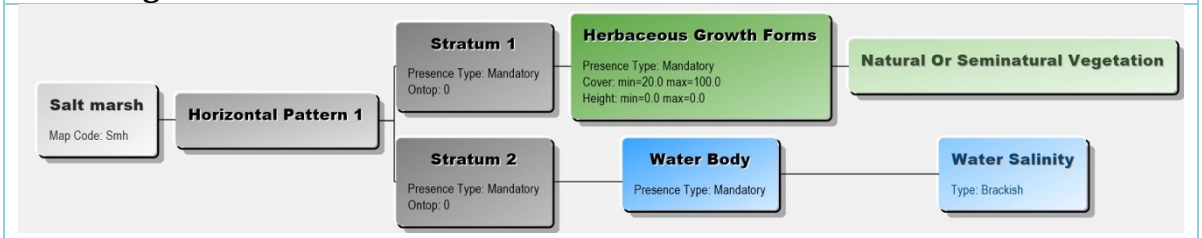
Salt march - Smh

Picture

Description

This class is very basic, and generic being constituted by two mandatory stratum that defines the overall class structure that is herbaceous growth form and water body.
The element herbs have two attributes:
● Cover expressed in percent of plant covering the ground ranging from 20 - 100 percent.
● Vegetation artificiality in this case is defined as natural vegetation.
The element water body has two attributes:
● Artificiality of water body is natural.
● Water salinity is brackish.

LCCS diagram



Class expansion for herbs dominated area

The regional reference schema gives to the user a wide possibility to enrich the thematic details of each class. This can be done using the shared dictionary of attributes of the ISO standard LCML. Following this process, each further enrichment of legend categories will assure a full harmonization process of different legends that for different reasons (legend scope, terrain knowledge etc.) wants to have different thematic attributes to define their classes. In this specific context, the foreseen suggested class thematic enrichment attributes could be the following:

Physiognomic structural properties:

- **Height:** more specific height can be used to better characterize the basic element herb.
- **Leaf phenology:** specific leaf phenology for each growth form can be defined.
- **Adding different strata of growth forms:** in addition to the main stratas characterizing. this class other strata with different growth, forms can be added.
- **Water body:** Water artificiality and salinity type can be further added.
- **Water periodic variation:** Period type and persistence period can be added.

Other attributes:

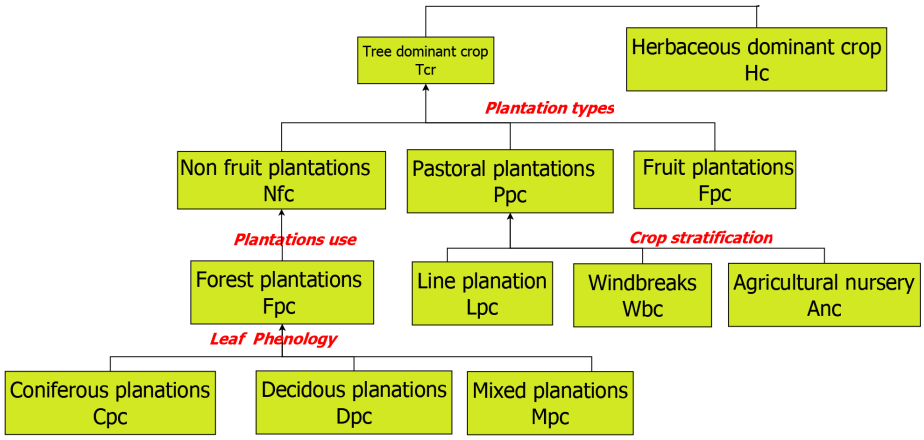
- **Floristic name:** intended as the floristic name of the plant species.
- **Grazing:** percentage of the intensity of grazing can be added for herbs.
- **Geographic location or altitude:** intended as any information related to a specific geographic location and or altitude ranges.
- **Any other attributes:** other attributes derived from the LCML shared dictionary.

Section III
Cultivated rainfed - Cr

Tree crop plantation – Tcr

It corresponds to areas with cultivated rainfed agriculture where the growth form tree is dominant. The structure of the tree crop plantation can be seen Figure 18.

Figure A.5 Structure of tree crop plantation



Derived classes (first level)

Two derived classes are foreseen classified as forest plantation and orchards, sub-divided according to the different plantation types that characterize the dominant element tree.

Non fruit plantation (Nfc)

It corresponds to areas with cultivated rainfed agriculture where the growth form tree is dominant are not furit.

Pastoral plantation (Ppc)

Pastoral farming (also known in some regions as ranching, livestock farming or grazing) is aimed at producing livestock, rather than growing crops.

Fruit plantation (Fpc)

It corresponds to plantation of trees which bears fruit that is consumed or used by animals and humans

Derived classes (second level)

A further sub-division is made both for the forest plantation and orchards. At this level the classes have a detailed structural aspect. A further expansion of the thematic details can be done, if necessary, as listed in the class expansion section.

Forest plantation - Nfc

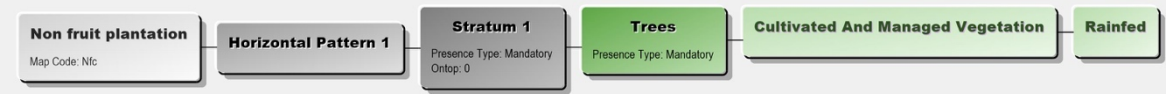
Picture

Description

This class describes the generic aspect of the evergreen forest plantation. It is composed of a single mandatory stratum that defines the overall structure of the class. The element tree in this class has the following attributes:

- Height of the planted trees varies depending on the plantation type.
- It is rainfed forest plantation area.
- Vegetation artificiality in this case is defined as cultivated vegetation.

LCCS diagram



Coniferous plantation– Cpc

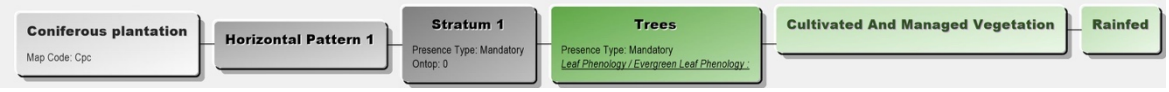
Picture

Description

This class describes the generic aspect of the mixed forest plantation. It is composed of a single mandatory stratum that defines the overall structure of the class. The element tree in this class has the following attributes:

- Height of the planted trees varies depending on the plantation type.
- It is rainfed forest plantation area.
- Vegetation artificiality in this case is defined as cultivated vegetation.
- Deciduous and/or evergreen leaf phenology is 40 – 60 percent.

LCCS diagram



Decidous plantation- Dpc

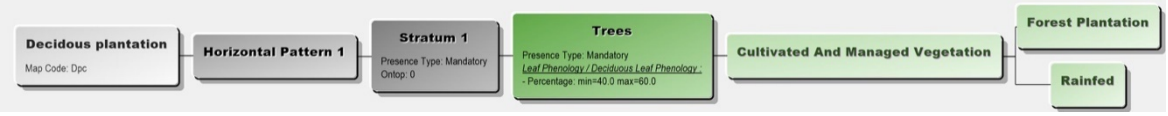
Picture

Description

This class describes the generic aspect of the deciduous forest plantation. It is composed of a single mandatory stratum that defines the overall structure of the class. The element tree in this class has the following attributes:

- Height of the planted trees varies depending on the plantation type.
- It is rainfed forest plantation area.
- Vegetation artificiality in this case is defined as cultivated vegetation.
- Deciduous leaf phenology is 40 – 60 percent.

LCCS diagram



Mixed plantation- Mpc

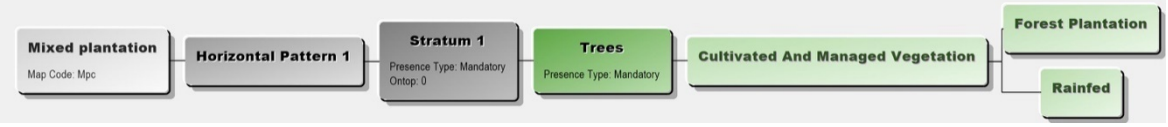
Picture

Description

This class describes the generic aspect of the deciduous forest plantation. It is composed of a single mandatory stratum that defines the overall structure of the class. The element tree in this class has the following attributes:

- Height of the planted trees varies depending on the plantation type.
- It is rainfed forest plantation area.
- Vegetation artificiality in this case is defined as cultivated vegetation.
- Deciduous leaf phenology is 40 – 60 percent.

LCCS diagram



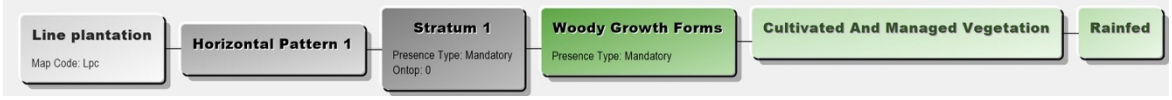
Line plantation- Lpc

Picture

Description

This level corresponds to tree planted using a line planting method. The lines were 2 m wide with 8 m secondary forest between lines.

LCCS diagram



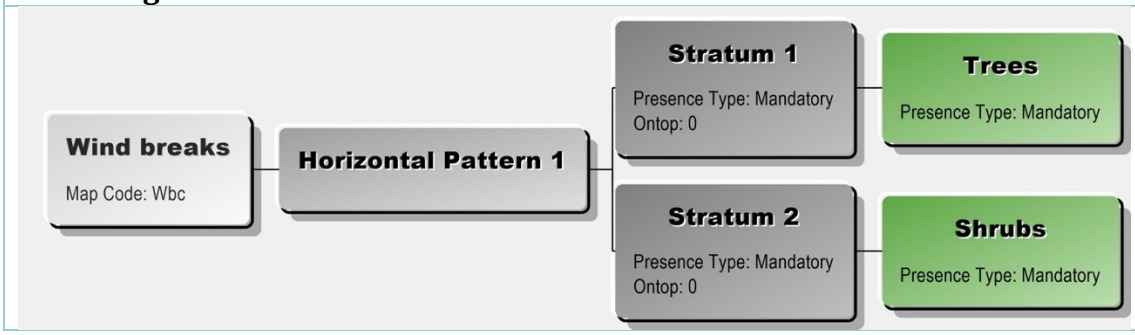
Wind breaks - Wbc

Picture

Description

It corresponds to windbreak (shelterbelt) is a planting usually made up of one or more rows of trees or shrubs planted in such a manner as to provide shelter from the wind and to protect soil from erosion.

LCCS diagram



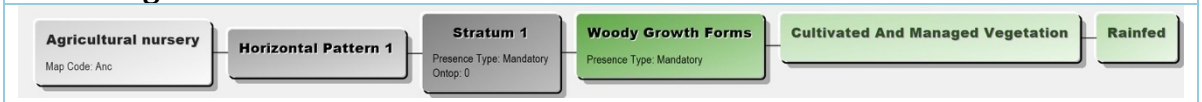
Agricultural nursery - Anc

Picture

Description

It corresponds to a place where plants are propagated and grown to a desired size. Mostly the plants concerned are for gardening, forestry, or conservation biology, rather than agriculture.

LCCS diagram



Class expansion for tree crop plantation

The regional reference schema gives to the user a wide possibility to enrich the thematic details of each class. This can be done using the shared dictionary of attributes of the ISO standard LCML. Following this process, each further enrichment of legend categories will assure a full harmonization process of different legends that for different reasons (legend scope, terrain knowledge etc.) wants to have different thematic attributes to define their classes. In this specific context, the foreseen suggested class thematic enrichment attributes could be the following:

Physiognomic structural properties:

- **Height:** more specific height can be used to better characterize the basic element tree.
- **Leaf phenology:** specific leaf phenology for each growth form can be defined.
- **Leaf type:** specific leaf type for each growth form can be added.
- **Adding different strata of growth forms:** in addition to the main strata characterizing this class other strata with different growth, forms can be added.

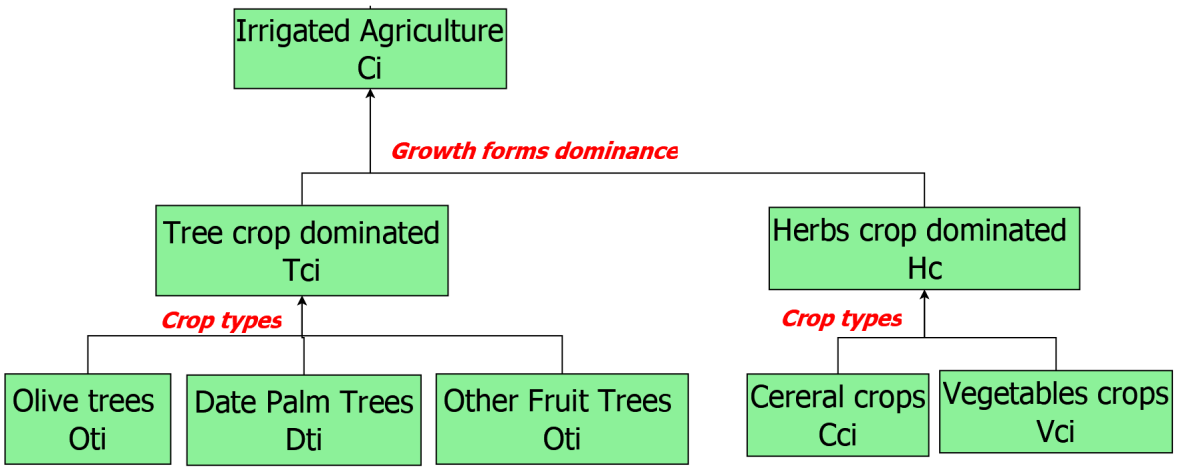
Other attributes:

- **Floristic name:** intended as the floristic name of the plant species.
- **Geographic location or altitude:** intended as any information related to a specific geographic location and or altitude ranges.
- **Field size:** intended as the field size for cultivated rainfed can be added.
- **Plant spreading geometry:** intended as geometry of the spreading plant can be added.
- **Any other attributes:** other attributes derived from the LCML shared dictionary.

Irrigated agriculture – Ci

The Irrigated agriculture corresponds to areas with cultivated Irrigated where the growth form shrub and tree are dominant.

Figure A.6 Structure of Irrigated agriculture



Derived classes (first level)

Two derived classes are foreseen classified as tree crop dominated and herbs crop dominated, sub-divided according to the different plant stratification that characterize the dominant element plantation.
Tree crop dominated (irrigated) Tci Irrigated tree crop dominated corresponds to areas with cultivated irrigated agriculture where the growth form tree is dominant.
Herbeceous crop dominated (irrigated) Hci It corresponds to areas with cultivated irrigated agriculture where the growth form herb is dominant. Herbaceous crops are cultivated or managed plants which do not have any woody stem above ground.

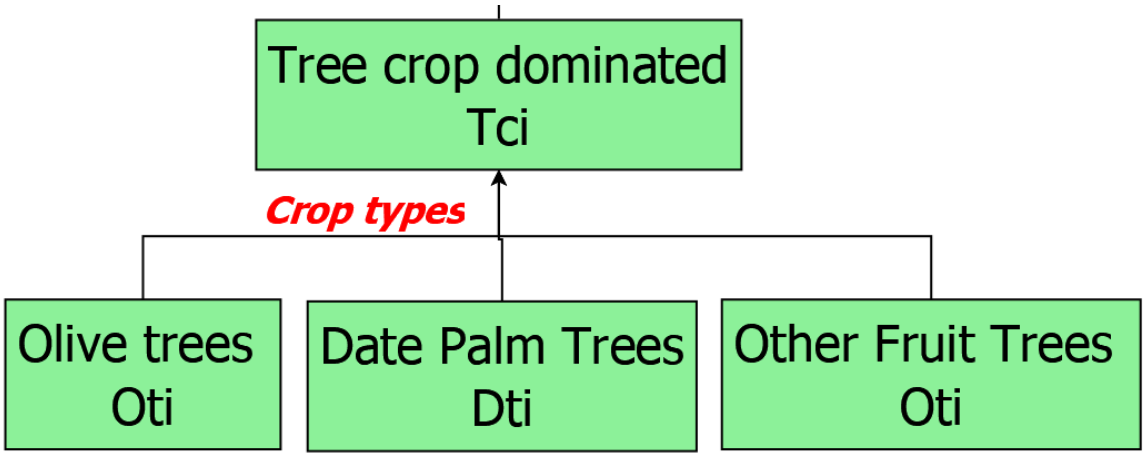
Derived classes (second level)

A further sub-division is made both for the tree crop dominated and herbs crop dominated. At this level the classes have a detailed structural aspect. A further expansion of the thematic details can be done, if necessary, as listed in the class expansion section.

Irrigated tree crop dominated – TCi

Irrigated tree crop dominated corresponds to areas with cultivated rainfed agriculture where the growth form tree is dominant. The structure of tree crop can be seen in Figure 20.

Figure 13. Structure of Irrigated tree crop dominated



Derived classes (first level)

Three derived classes are foreseen classified as annual herb cultivation and shifting herb cultivation, sub-divided according to the different crop cultivation period that characterize the dominant element plantation.

Olive trees (Oti)

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element shrub with the following attributes:

- It is irrigated plantation area with rotational period from 1 to 3 years.
- Vegetation artificiality in this case is defined as cultivated vegetation.

Date palm trees (Dti)

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element shrub with the following attributes:

- It is irrigated plantation area with rotational period from 1 to 2 years.
- Vegetation artificiality in this case is defined as cultivated vegetation.
- Cover percentage is 15 – 30 percent.

An extra basic stratum for herb growth form is present with following attributes:

- Vegetation artificiality in this case is defined as cultivated vegetation.
- Cover percentage is 30 – 85 percent.

Other fruit trees (Ofti)

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element shrub with the following attributes:

- It is irrigated plantation area with rotational period from 1 to 50 years.
- Vegetation artificiality in this case is defined as cultivated vegetation.
- Cover percentage is 15 – 30 percent.

An extra basic stratum for herb growth form is present with following attributes:

- Vegetation artificiality in this case is defined as cultivated vegetation.
- Cover percentage is 30 – 85 percent.

Olive trees – Oti

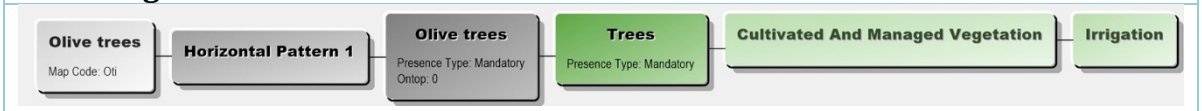
Picture

Description

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element shrub with the following attributes:

- It is irrigated plantation area with rotational period from 1 to 3 years.
- Vegetation artificiality in this case is defined as cultivated vegetation.

LCCS diagram



Date palm trees - Dti

Picture

Description

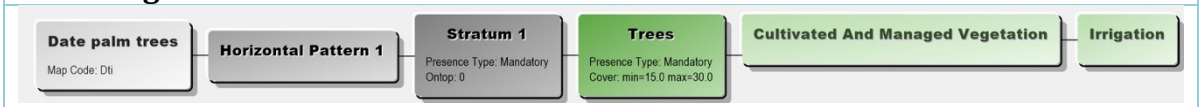
This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element shrub with the following attributes:

- It is irrigated plantation area with rotational period from 1 to 2 years.
- Vegetation artificiality in this case is defined as cultivated vegetation.
- Cover percentage is 15 – 30 percent.

An extra basic stratum for herb growth form is present with following attributes:

- Vegetation artificiality in this case is defined as cultivated vegetation.
- Cover percentage is 30 – 85 percent.

LCCS diagram



Other fruit trees - Ofti

Picture

Description

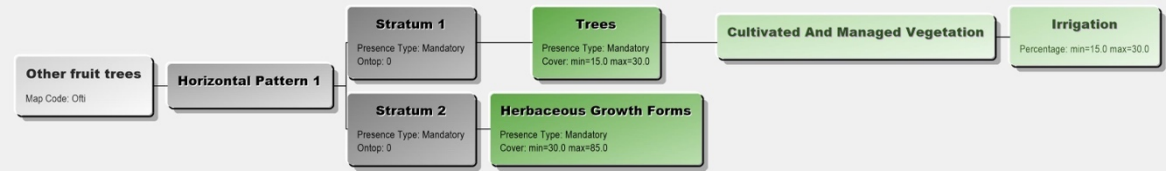
This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element shrub with the following attributes:

- It is irrigated plantation area with rotational period from 1 to 50 years.
- Vegetation artificiality in this case is defined as cultivated vegetation.
- Cover percentage is 15 – 30 percent.

An extra basic stratum for herb growth form is present with following attributes:

- Vegetation artificiality in this case is defined as cultivated vegetation.
- Cover percentage is 30 – 85 percent

LCCS diagram



Class expansion for tree crop dominated (irrigated)

The regional reference schema gives to the user a wide possibility to enrich the thematic details of each class. This can be done using the shared dictionary of attributes of the ISO standard LCML. Following this process, each further enrichment of legend categories will assure a full harmonization process of different legends that for different reasons that is legend scope, terrain knowledge etc. wants to have different thematic attributes to define their classes. In this specific context, the foreseen suggested class thematic enrichment attributes could be the following:

Physiognomic structural properties:

- **Height:** more specific height can be used to better characterize the basic element herb.
- **Leaf phenology:** specific leaf phenology for each growth form can be defined.
- **Adding different strata of growth forms:** in addition to the main strata characterizing this class other strata with different growth, forms can be added.

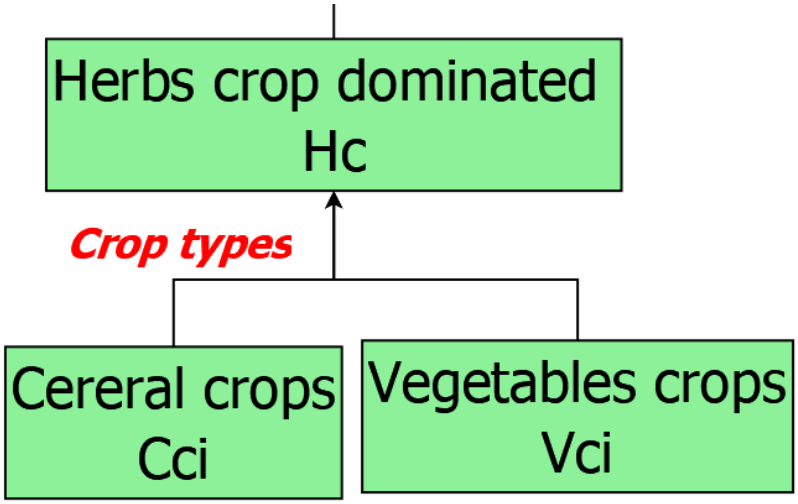
Other attributes:

- **Floristic name:** intended as the floristic name of the plant species.
- **Geographic location or altitude:** intended as any information related to a specific geographic location and or altitude ranges.
- **Seeding time:** information about month that crop was sown can be added
- **Any other attributes:** other attributes derived from the LCML shared dictionary.

Herb crop plantation – Hci

It corresponds to areas with cultivated irrigated agriculture where the growth form herb is dominant. The structure of the herb crop plantation can be seen in Figure 23.

Figure 14. Structure of herb crop plantation



Derived classes (first level)

Two derived classes are foreseen classified as single crop and multiple crops, sub-divided according to the different cropping intensity that characterize the dominant element plantation.

Cereal crops (Cci)

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element shrub with the following attributes:

- It is irrigated plantation area with single herbaceous crop.
- Vegetation artificiality in this case is defined as cultivated vegetation.

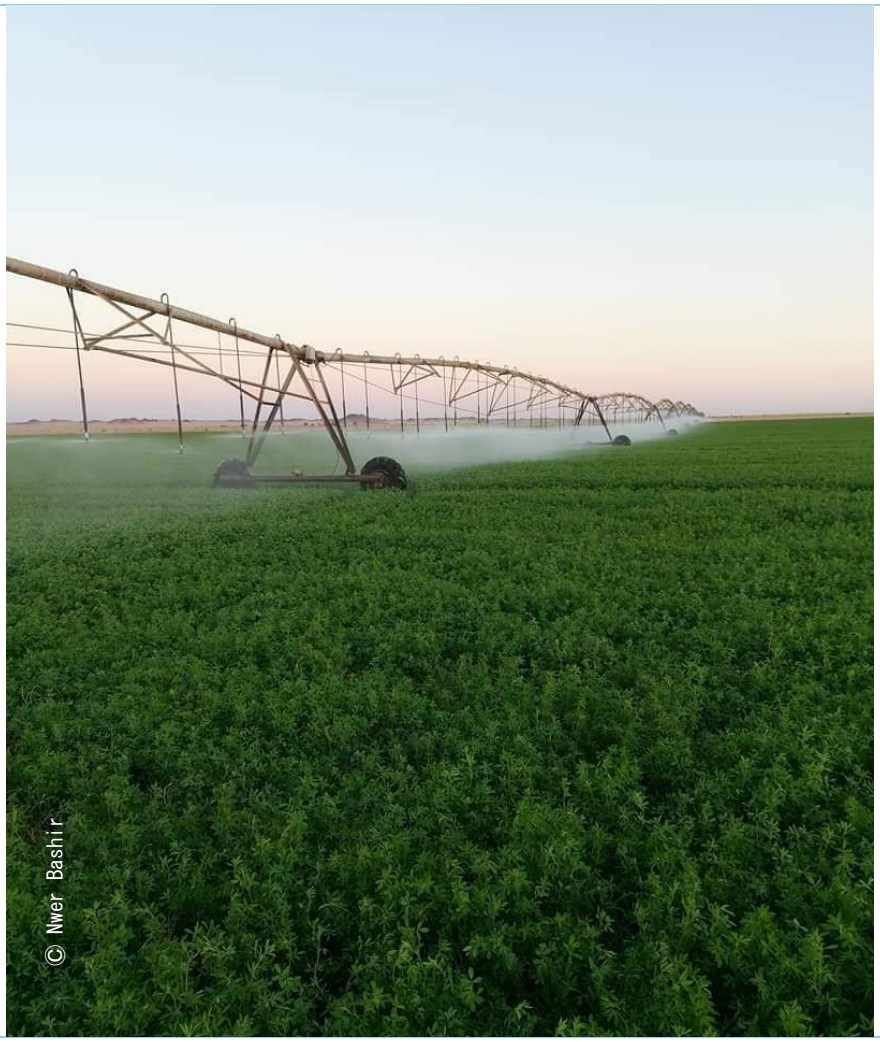
Vegetable crops (Vci)

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element shrub with the following attributes:

- It is irrigated plantation area with multiple herbaceous crops.
- Multiple crops with rotational same year period from 3 to 6 years.
- Vegetation artificiality in this case is defined as cultivated vegetation.

Cereal crops- Cci

Picture

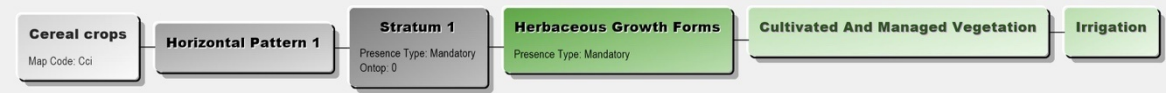


Description

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element herbs with the following attributes:

- It is irrigated plantation area with single herbaceous crop.
- Vegetation artificiality in this case is defined as cultivated vegetation.

LCCS diagram



Vegetable crops- Vci

Picture

Description

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element crop with the following attributes:

- It is irrigated plantation area with multiple herbaceous crops.
- Multiple crops with rotational same year period from 3 to 6 years.
- Vegetation artificiality in this case is defined as cultivated vegetation.

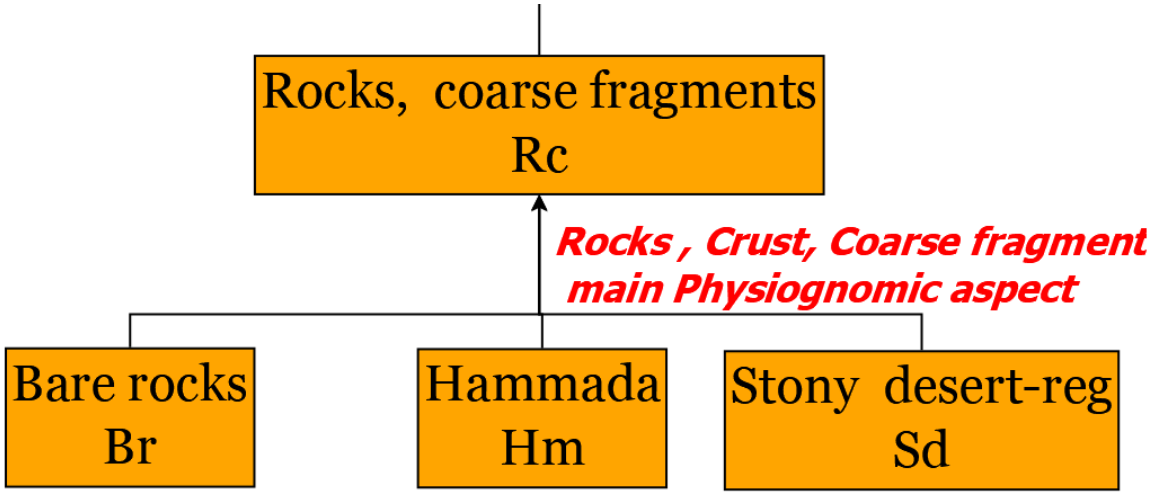
LCCS diagram

Section VI
Natural surfaces – Sn

Rocks, coarse fragments – Tr

It corresponds to areas with natural surfaces where the rocky and coarse fragments are dominant. The presence of sub-surfaces is recognized with main physiognomic aspect. The structure of the rocks, coarse fragments can be seen in Figure 26.

Figure A.7 Structure of rocks, coarse fragments



Derived classes (first level)

Three derived classes are foreseen classified as bare rocks, bowal lateritic crust and stony desert.

Bare rocks (Sr)

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element rock.

Hammada (Hrr)

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element hard pans with iron pan/laterite type.

Stony Desert – Reg (Std)

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element coarse fragment minerals.

Derived classes (second level)

A further expansion of the thematic details can be done, if necessary, as listed in the class expansion section.

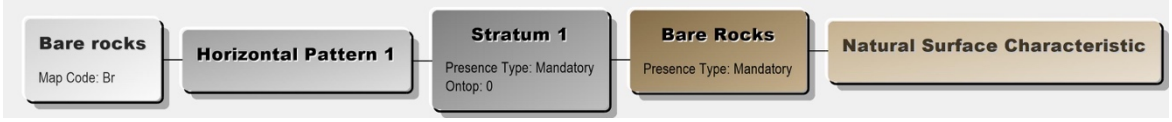
Bare rocks - Br

Picture

Description

It corresponds to areas with natural surfaces where bare rocks are dominant.

LCCS diagram



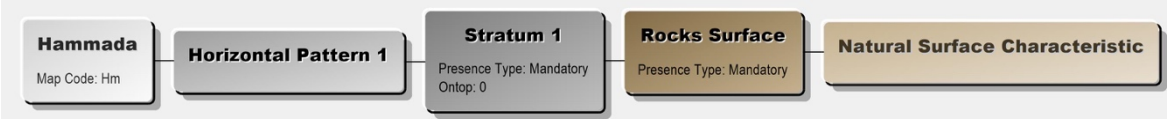
Hammada-Hm

Picture

Description

This class describes a rock-floored or rock-strewn desert region especially in the Sahara.

LCCS diagram



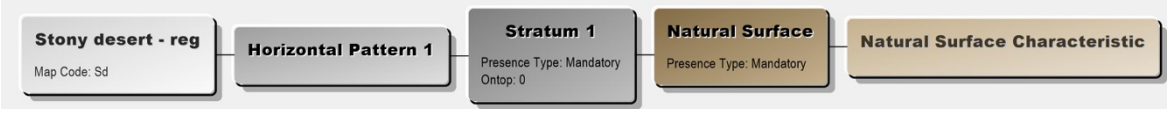
Stony desert - Std

Picture

Description

This class describes a desert surface covered with closely packed, interlocking angular or rounded rock fragments of pebble and cobble size. It is also called desert pavement.

LCCS diagram



Class expansion for rocks, coarse fragments

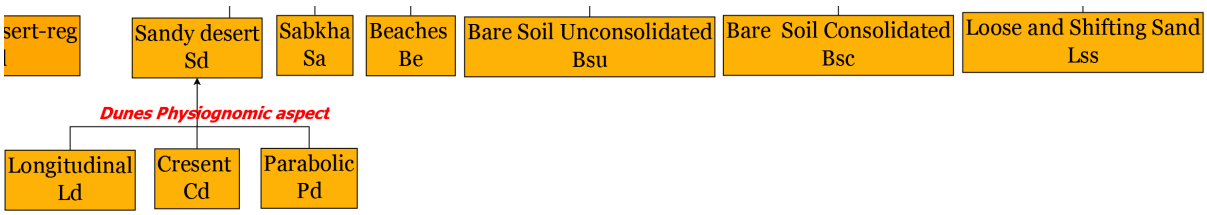
The regional reference schema gives to the user a wide possibility to enrich the thematic details of each class. This can be done using the shared dictionary of attributes of the ISO standard LCML. Following this process, each further enrichment of legend categories will assure a full harmonization process of different legends that for different reasons (legend scope, terrain knowledge etc.) wants to have different thematic attributes to define their classes. In this specific context, the foreseen suggested class thematic enrichment attributes could be the following:

- **Rock type:** rock type and rock age type for consolidated surface characteristics can be added.
- **Soil type:** soil type for unconsolidated surface characteristics can be added.
- **Geographic location or altitude:** intended as any information related to a specific geographic location and or altitude ranges.
- **Any other attributes:** other attributes derived from the LCML shared dictionary.

Soil sand deposit – Ss

It corresponds to areas with natural surfaces where the soil, sand and deposits are dominant. The presence of sub-surfaces is recognized with main physiognomic aspect. The structure of the soil sand deposit can be seen in Figure 27.

Figure A.8 Structure of soil, sand deposit



Derived classes (first level)

Four derived classes are foreseen classified as sandy desert, salt deposit, bare soil, and beaches, sub-divided according to the different physiognomic aspect.

Sandy desert (Sd)

This class is very basic, and generic being constituted by one mandatory stratum that defines overall class structure. The strata are constituted by one basic element lose and shifting sand.

Longitudinal (Ld)

This class is very basic, and generic being constituted by one mandatory stratum that defines overall class structure. The strata are constituted by one basic element inorganic deposit with salt flat type.

Bare soil (Sn)

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element bare soil.

Beaches (P)

This class is very basic, and generic being constituted by one mandatory stratum that defines overall class structure. The strata are constituted by one basic element lose and shifting sand.

Cresent (Cd)

This class is very basic, and generic being constituted by one mandatory stratum that defines overall class structure. The strata are constituted by one basic element lose and shifting sand.

Sabkha (Sa)

Sabkha: are flat and very saline areas of sand or silt lying just above the water-table and often containing soft nodules and enterolithic veins of gypsum or anhydrite.

Parabolic (Pd)

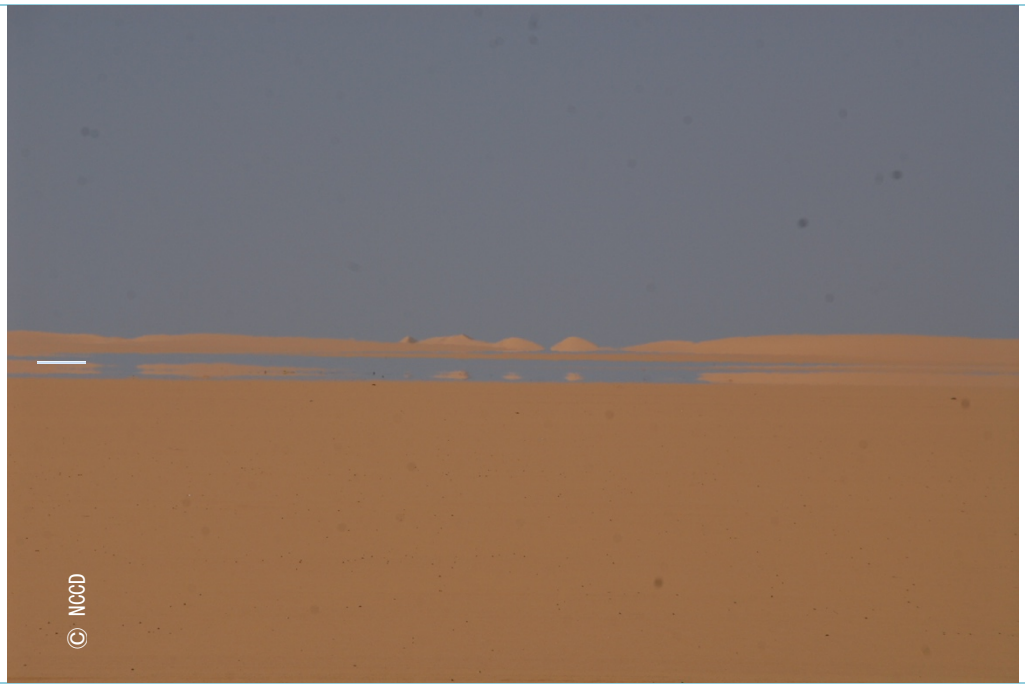
This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element bare soil.

Loose and shifting sand (Lss)

This class is very basic, and generic being constituted by one mandatory stratum that defines overall class structure. The strata are constituted by one basic element lose and shifting sand.

Sandy desert (Sd)

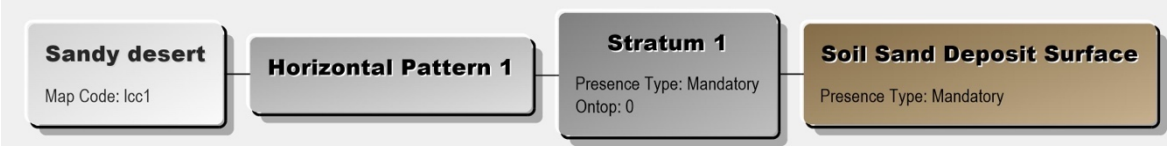
Picture



Description

This class is very basic, and generic being constituted by one mandatory stratum that defines overall class structure. The strata are constituted by one basic element lose and shifting sand.

LCCS diagram



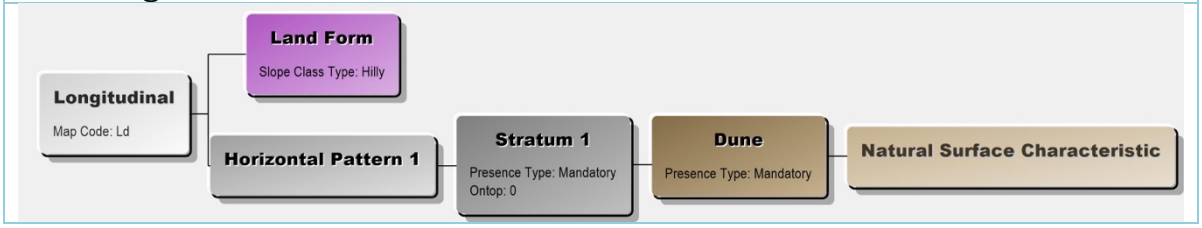
Longitudinal - Ld

Picture

Description

This class is very basic, and generic being constituted by one mandatory stratum that defines overall class structure. The strata are constituted by one basic element inorganic deposit with salt flat type.

LCCS diagram



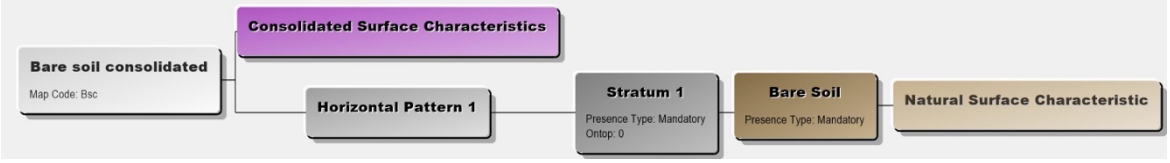
Bare soil Consolidated - Bsc

Picture

Description

This class is very basic, and generic being constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element bare soil.

LCCS diagram



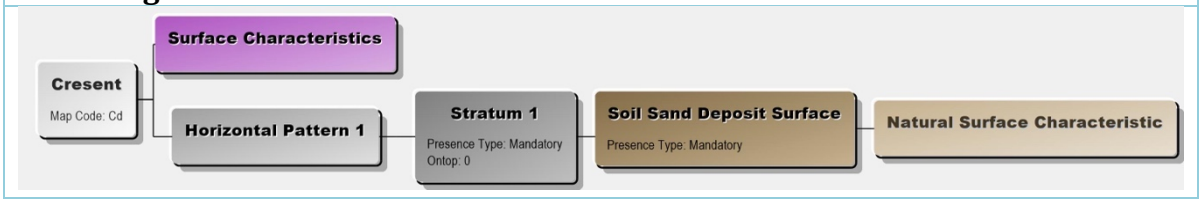
Cresent - Cd

Picture

Description

This class describes the generic aspect of dunes. It is constituted by one mandatory stratum that defines the overall class structure. The strata are constituted by one basic element dune with parabolic type.

LCCS diagram



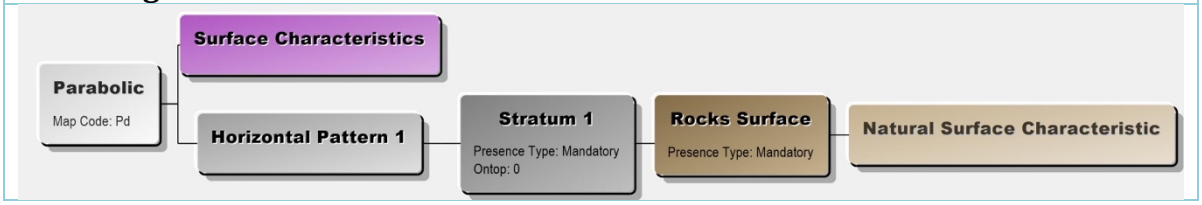
Parabolic - Pd

Picture

Description

This class describes parabolic dune are sand duens forms when strong winds erode a section of the vegetated sand (commonly referred to as a blowout). It is also called U shape sand dunes.

LCCS diagram



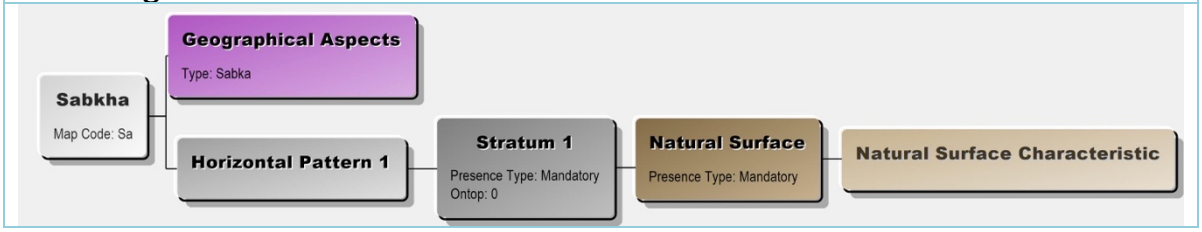
Sabkha - Sa

Picture

Description

Sabkha: are flat and very saline areas of sand or silt lying just above the water-table and often containing soft nodules and enterolithic veins of gypsum or anhydrite.

LCCS diagram



Class expansion for soil sand deposit

The regional reference schema gives to the user a wide possibility to enrich the thematic details of each class. This can be done using the shared dictionary of attributes of the ISO standard LCML. Following this process, each further enrichment of legend categories will assure a full harmonization process of different legends that for different reasons (legend scope, terrain knowledge etc.) wants to have different thematic attributes to define their classes. In this specific context, the foreseen suggested class thematic enrichment attributes could be the following:

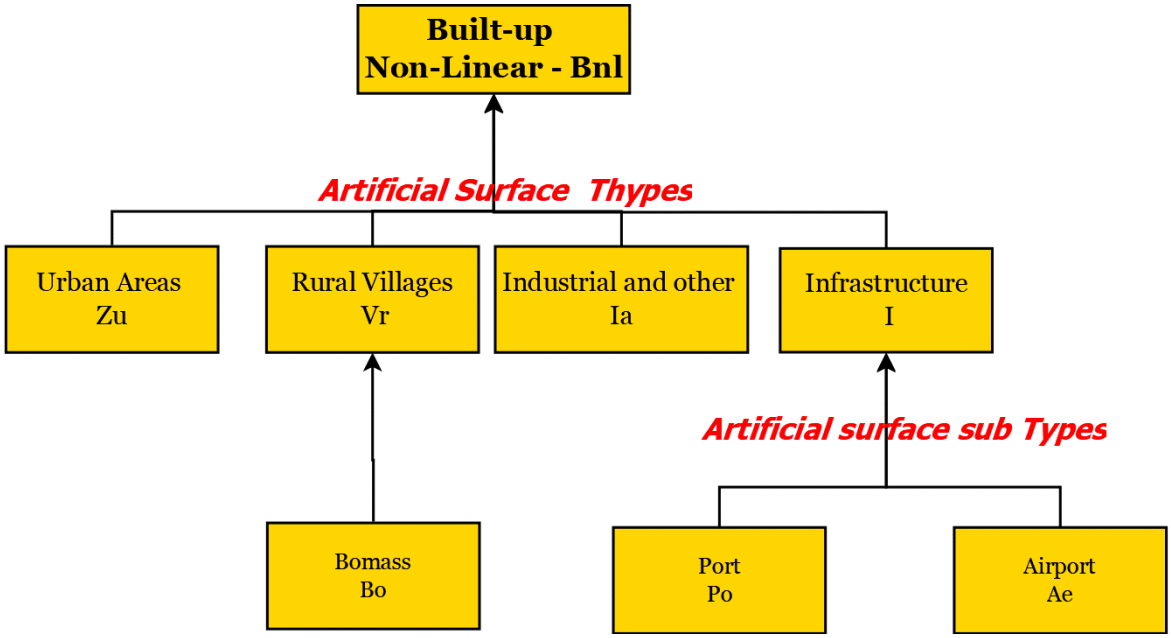
- **Rock type:** rock type and rock age type for consolidated surface characteristics can be added.
- **Soil type:** soil type for unconsolidated surface characteristics can be added.
- **Geographic location or altitude:** intended as any information related to a specific geographic location and or altitude ranges.
- **Any other attributes:** other attributes derived from the LCML shared dictionary.

Section VII
Artificial surfaces – Ast

Built-up Nonlinear – Bnl

It corresponds to artificial and impervious surface which are paved with hard materials are built-up non-linear. The presence of sub-surfaces is recognized with types of artificial surface.

Figure A.9 Structure of built-up non-linear



Derived classes (first level)

Four derived classes are foreseen classified as urban area, rural villages, industrial and infrastructure, sub-divided according to the different artificial surface types.

Urban areas (Zu)

Artificial surfaces with urban area geographical aspect including buildings, other constructions and other artificial surfaces.

Rural villages (Vr)

Artificial surfaces with rural area geographical aspect including buildings and other artificial surfaces.

Industrial and others (Ia)
Artificial surfaces including industrial areas and other artificial surfaces.

Infrastructure (I)
Artificial surfaces including infrastructure and other artificial surfaces.

Derived classes (second level)

A further sub-division is made for rural villages and infrastructure. At this level the classes have a detailed structural aspect. A further expansion of the thematic details can be done, if necessary, as listed in the class expansion section.

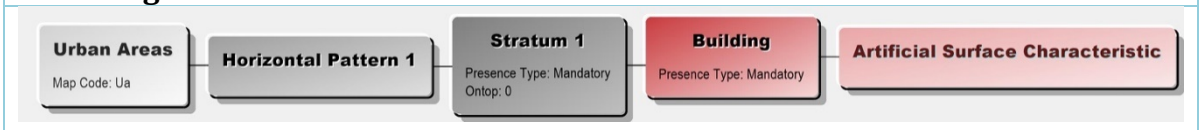
Urban areas - Ua

Picture

Description

Artificial surfaces with urban area geographical aspect including buildings, other constructions and other artificial surfaces.

LCCS diagram



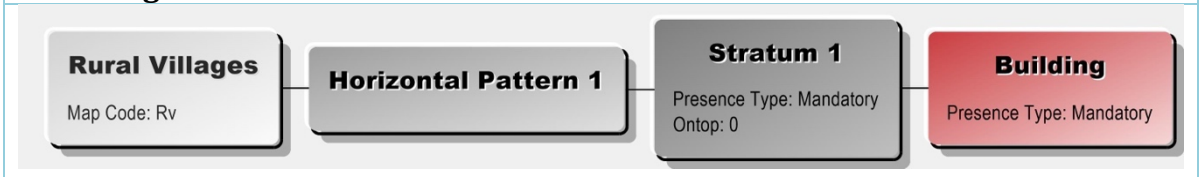
Rural villages - Rv

Picture

Description

Artificial surfaces with rural area geographical aspect including buildings and other artificial surfaces.

LCCS diagram



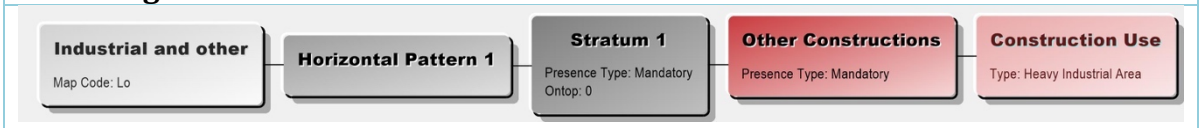
Industrial and other - Io

Picture

Description

Artificial surfaces including industrial areas and other artificial surfaces.

LCCS diagram



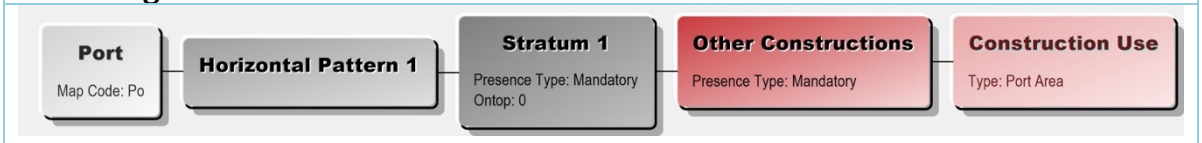
Port – Po

Picture

Description

It is a built up – nonlinear area for ships.

LCCS diagram



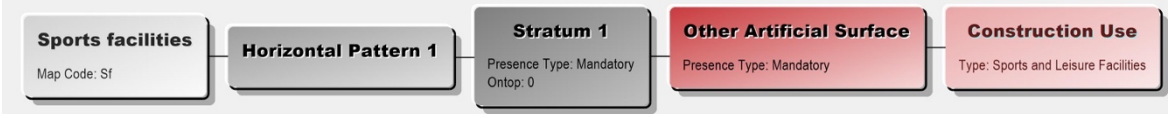
Sports facilities - Sf

Picture

Description

It corresponds to sports venue is a building, structure, or place in which a sporting competition is held. A stadium or arena is a place or venue for sports or other events and consists of a field or stage either partly or completely surrounded by a tiered structure designed to allow spectators to stand or sit and view the event.

LCCS diagram



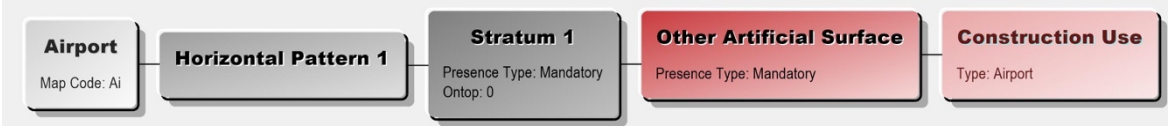
Airport – Ai

Picture

Description

It is a built-up nonlinear area which is used for flights to take off and land.

LCCS diagram



Class expansion for built-up non-linear

The regional reference schema gives to the user a wide possibility to enrich the thematic details of each class. This can be done using the shared dictionary of attributes of the ISO standard LCML. Following this process, each further enrichment of legend categories will assure a full harmonization process of different legends that for different reasons (legend scope, terrain knowledge etc.) wants to have different thematic attributes to define their classes. In this specific context, the foreseen suggested class thematic enrichment attributes could be the following:

Physiognomic structural properties:

- **Height:** more specific height can be used to better characterize the basic element.

Other attributes:

- **Construction status:** status of the construction objects can be added.
- **Construction use:** type of construction use can be added.
- **Any other attributes:** other attributes derived from the LCML shared dictionary.

Built-up linear and others – Bla

It corresponds to artificial surface which are built-up linear.

Figure A.10 LCCS diagram for built-up linear and others

Derived classes

A further expansion of the thematic details can be done, if necessary, as listed in the class expansion section.

Class expansion for built-up linear and others

The regional reference schema gives to the user a wide possibility to enrich the thematic details of each class. This can be done using the shared dictionary of attributes of the ISO standard LCML. Following this process, each further enrichment of legend categories will assure a full harmonization process of different legends that for different reasons (legend scope, terrain knowledge etc.) wants to have different thematic attributes to define their classes. In this specific context, the foreseen suggested class thematic enrichment attributes could be the following:

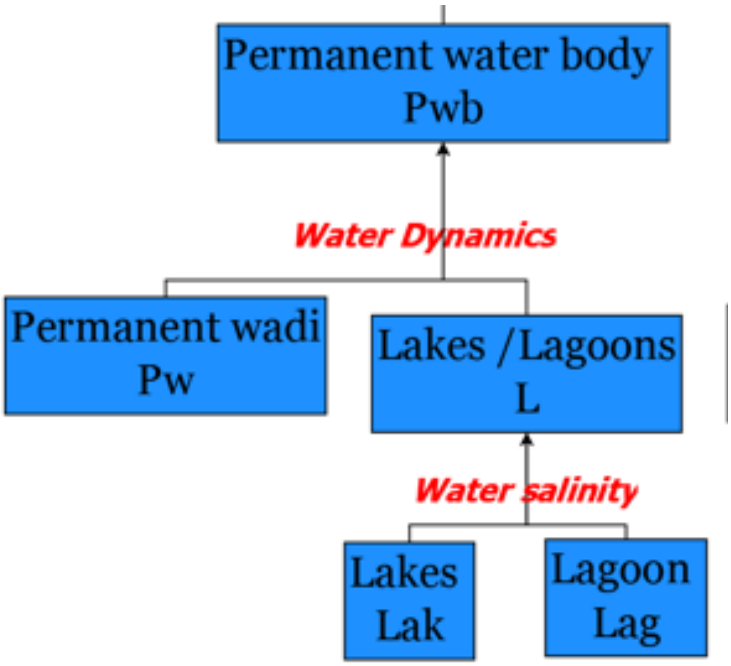
- **Road type:** types of roads can be added.
- **Construction status:** status of the construction objects can be added.
- **Construction use:** type of construction use can be added.
- **Any other attributes:** other attributes derived from the LCML shared dictionary.

Section VIII
Natural waterbodies – NW

Permanent Water body – Pwb

It corresponds to natural water bodies which are permanent feature in an area. They are further categorized based on water dynamics.

Figure 15. Structure of permanent waterbodies



Derived classes (second level)

A further sub-division is made for permanent water body. At this level the classes have a detailed structural aspect. A further expansion of the thematic details can be done, if necessary, as listed in the class expansion section.

Permanent wadi - Pwb

Picture

Description

This class describe the generic aspect of Wadi. It is constituted by two mandatory strata that defines the overall class structure. The strata are constituted by one basic element water body. Another basic element natural surface is also present. The element water body has following attributes:

- Weekly periodic variation.
- Water dynamics is flowing.
- Artificiality of water body is natural.
- Water salinity is fresh.

LCCS diagram

Lakes/Lagoons - L

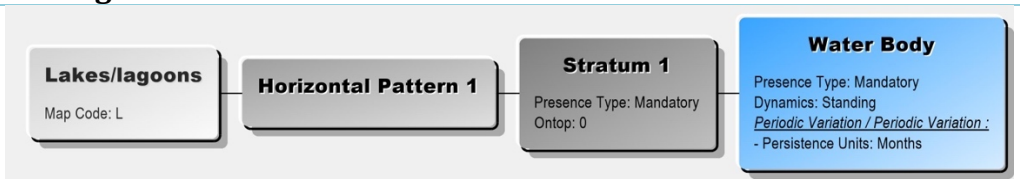
Picture

Description

A natural standing water reservoir that is bigger than a pond and has an irregular shape. This class consists of one mandatory strata. A basic element water body has following attributes:

- Monthly periodic variation.
- Water dynamics is standing.
- Water salinity

LCCS diagram



Lakes - Lek

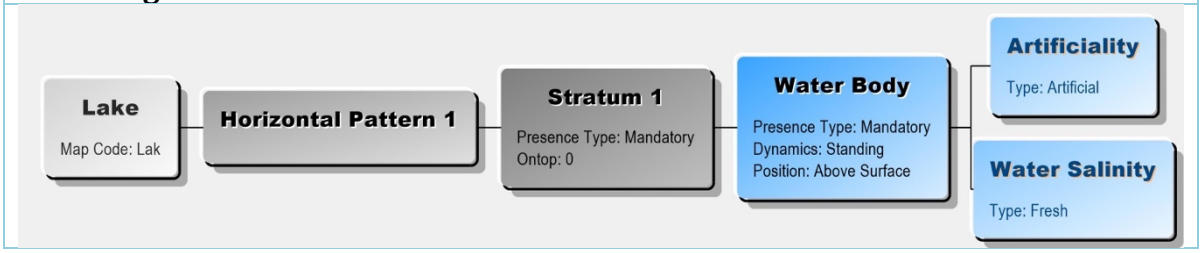
Picture

Description

A natural standing water reservoir that is bigger than a pond and has an irregular shape. This class consists of one mandatory strata. A basic element water body has following attributes:

- Monthly periodic variation.
- Water dynamics is standing.

LCCS diagram



Lagoons - Lag

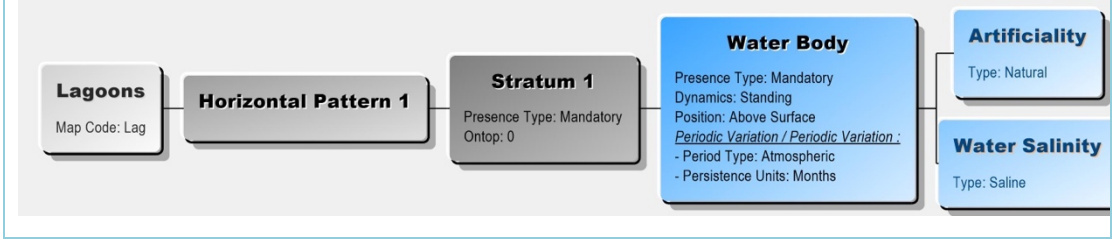
Picture

Description

A natural standing water reservoir that is bigger than a pond and has an irregular shape. This class consists of one mandatory strata. A basic element water body has following attributes:

- Monthly periodic variation.
- Water dynamics is standing.
- Water salinity

LCCS diagram



Class expansion for permanent water body

The regional reference schema gives to the user a wide possibility to enrich the thematic details of each class. This can be done using the shared dictionary of attributes of the ISO standard LCML. Following this process, each further enrichment of legend categories will assure a full harmonization process of different legends that for different reasons (legend scope, terrain knowledge etc.) wants to have different thematic attributes to define their classes. In this specific context, the foreseen suggested class thematic enrichment attributes could be the following:

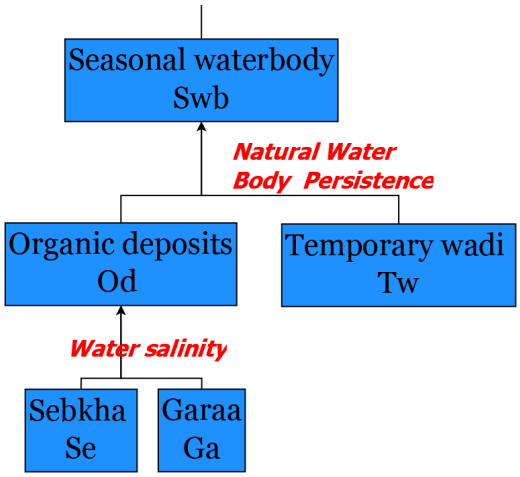
Other attributes:

- Water body dynamics: water type can be added that is flowing, or standing etc.
- Water body position: position of the waterbody can be added
- Water body: Water artificiality and salinity type can be further added.
- Water depth: Water depth can be added.

Seasonal Waterbodies – Swb

It corresponds to natural water bodies which are seasonal in an area. They are further categorized based on natural water body persistence.

Figure A.11 Structure of seasonal waterbodies



Derived classes (second level)

A further sub-division is made for seasonal water body. At this level the classes have a detailed structural aspect. A further expansion of the thematic details can be done, if necessary, as listed in the class expansion section.

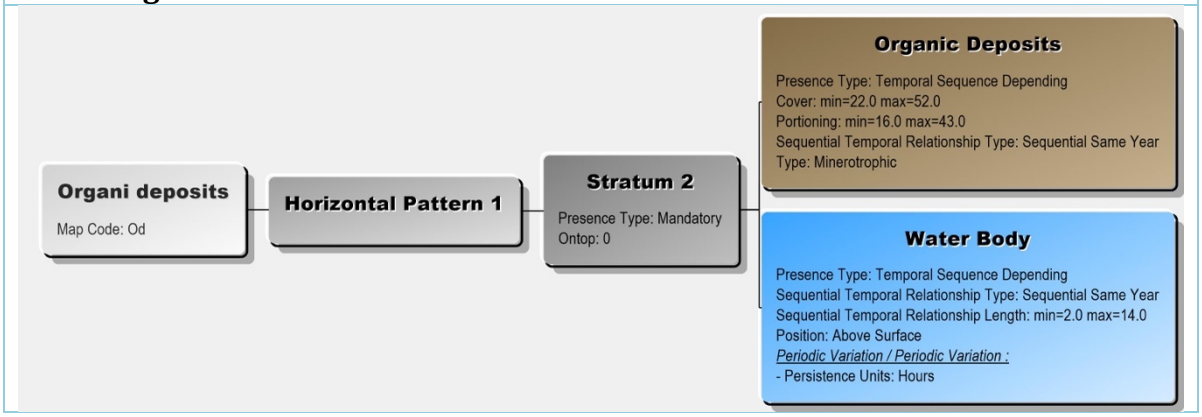
Organic deposits - Od

Picture

Description

When referring to organic deposits, it could mean natural accumulations of organic matter such as peat bogs or marshes.

LCCS diagram



Sabkha - Se

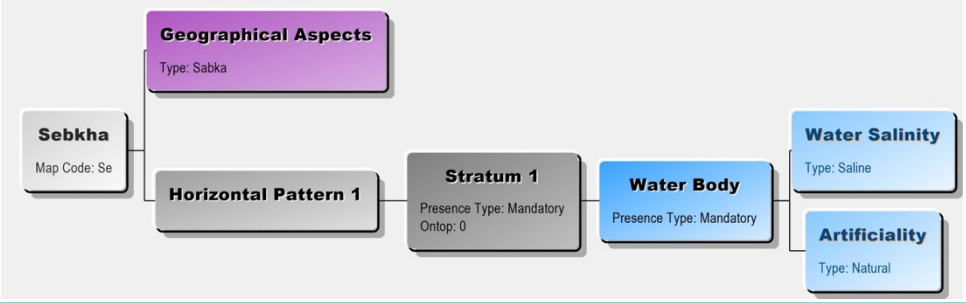
Picture

Description

Sabkha: are flat and very saline areas of sand or silt lying just above the water-table and often containing soft nodules and enterolithic veins of gypsum or anhydrite.

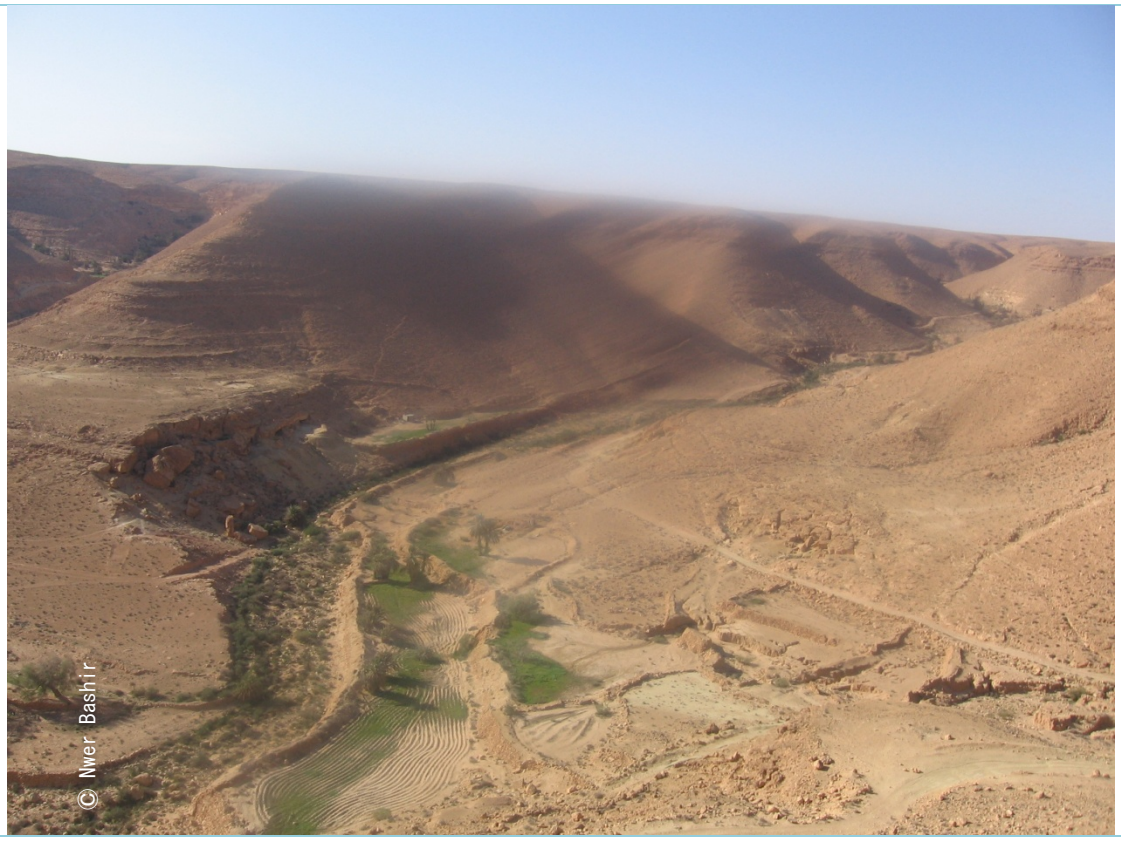
- Weekly periodic variation.
- Water dynamics is flowing.
- Artificiality of water body is natural.
- Water salinity is fresh.

LCCS diagram



Temporary Wadies - TW

Picture

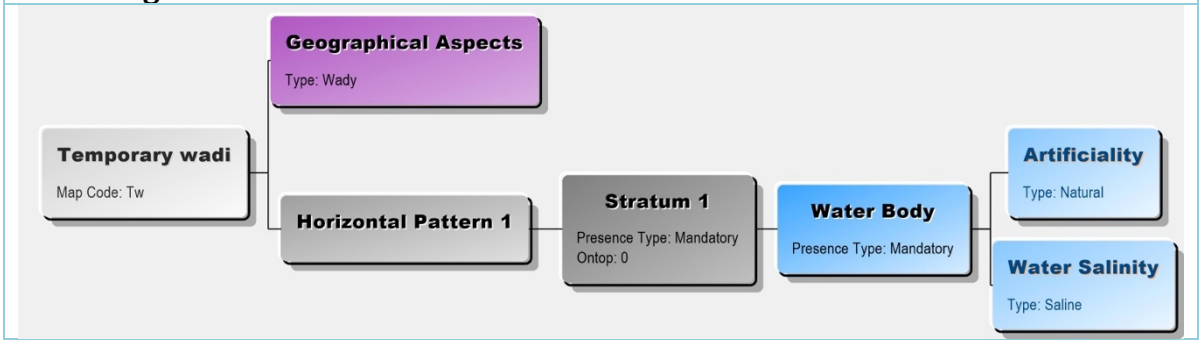


Description

This class describe the generic aspect of Wadi. It is constituted by two mandatory strata that defines the overall class structure. The strata are constituted by one basic element water body. Another basic element natural surface is also present. The element water body has following attributes:

- Weekly periodic variation.
- Water dynamics is flowing.
- Artificiality of water body is natural.
- Water salinity is fresh.

LCCS diagram



Class expansion for seasonal waterbodies

The regional reference schema gives to the user a wide possibility to enrich the thematic details of each class. This can be done using the shared dictionary of attributes of the ISO standard LCML. Following this process, each further enrichment of legend categories will assure a full harmonization process of different legends that for different reasons (legend scope, terrain knowledge etc.) wants to have different thematic attributes to define their classes. In this specific context, the foreseen suggested class thematic enrichment attributes could be the following:

- **Water body dynamics:** water type can be added that is flowing, or standing etc.
- **Water body position:** position of the waterbody can be added.
- **Water body:** Water artificiality and salinity type can be further added.
- **Water depth:** Water depth can be added.
- **Water periodic variation:** Period type and persistence period can be added.
- **Any other attributes:** other attributes derived from the LCML shared dictionary.

Section IX
Artificial waterbodies - Ea

It corresponds to artificial water bodies which are permanent and/or seasonal feature in an area. Th UML diagram for artificial water bodies is provided in Figure 33.

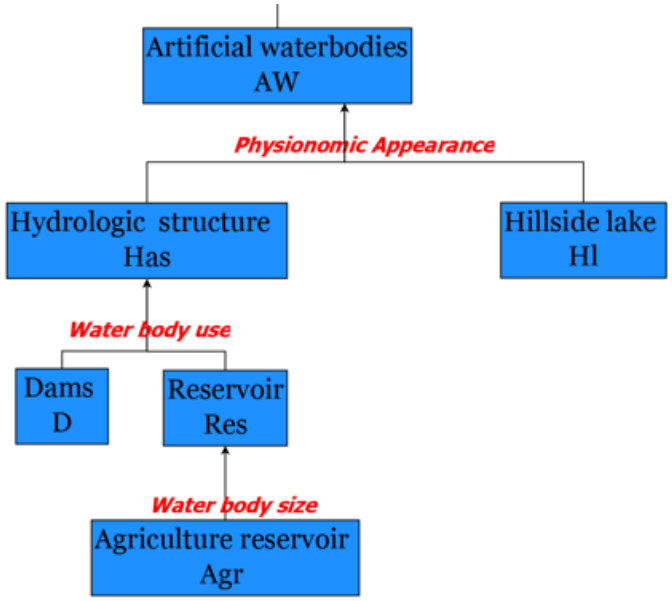
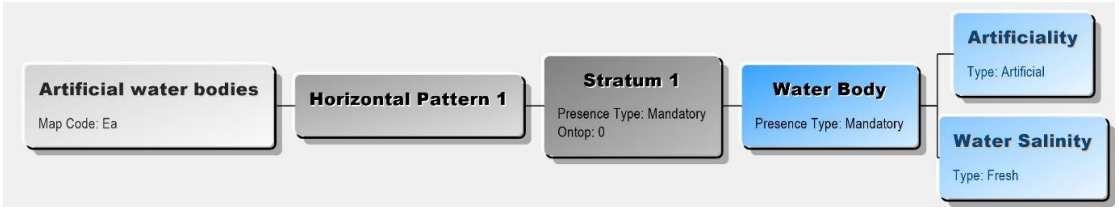


Figure 16. LCCS diagram for artificial waterbodies



Derived classes (second level)

A further expansion of the thematic details can be done, if necessary, as listed in the class expansion section.

Class expansion for artificial waterbodies

The regional reference schema gives to the user a wide possibility to enrich the thematic details of each class. This can be done using the shared dictionary of attributes of the ISO standard LCML. Following this process, each further enrichment of legend categories will assure a full harmonization process of different legends that for different reasons (legend scope, terrain knowledge etc.) wants to have different thematic attributes to define their classes. In this specific context, the foreseen suggested class thematic enrichment attributes could be the following:

- **Water body dynamics:** water type can be added that is flowing, or standing etc.
- **Water body position:** position of the waterbody can be added.
- **Water body:** Water artificiality and salinity type can be further added.
- **Water depth:** Water depth can be added.
- **Water periodic variation:** Period type and persistence period can be added.
- **Any other attributes:** other attributes derived from the LCML shared dictionary.

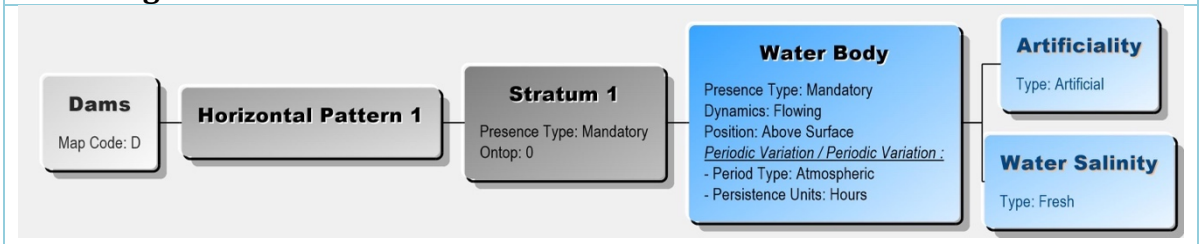
Dams - D

Picture

Description

This class describe a barrier that stops or restricts the flow of surface water or underground streams.

LCCS diagram



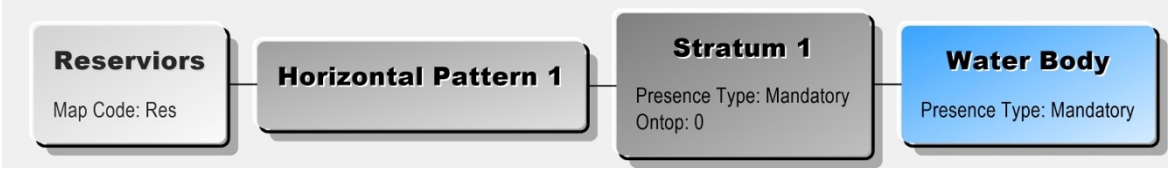
Reservoirs- Res

Picture

Description

This class describe an artificial lake where water is stored.

LCCS diagram



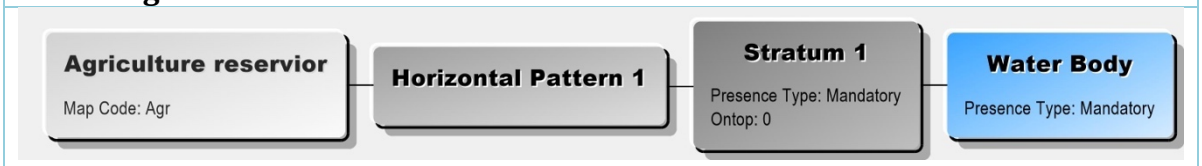
Agriculture reservoir - Agr

Picture

Description

This class describe small farm reservoir to accommodate excess rainwater during the rainy season. The water collected is then used as a source of supplementary irrigation for the cultivation of high-value economic commodities in the dry season.

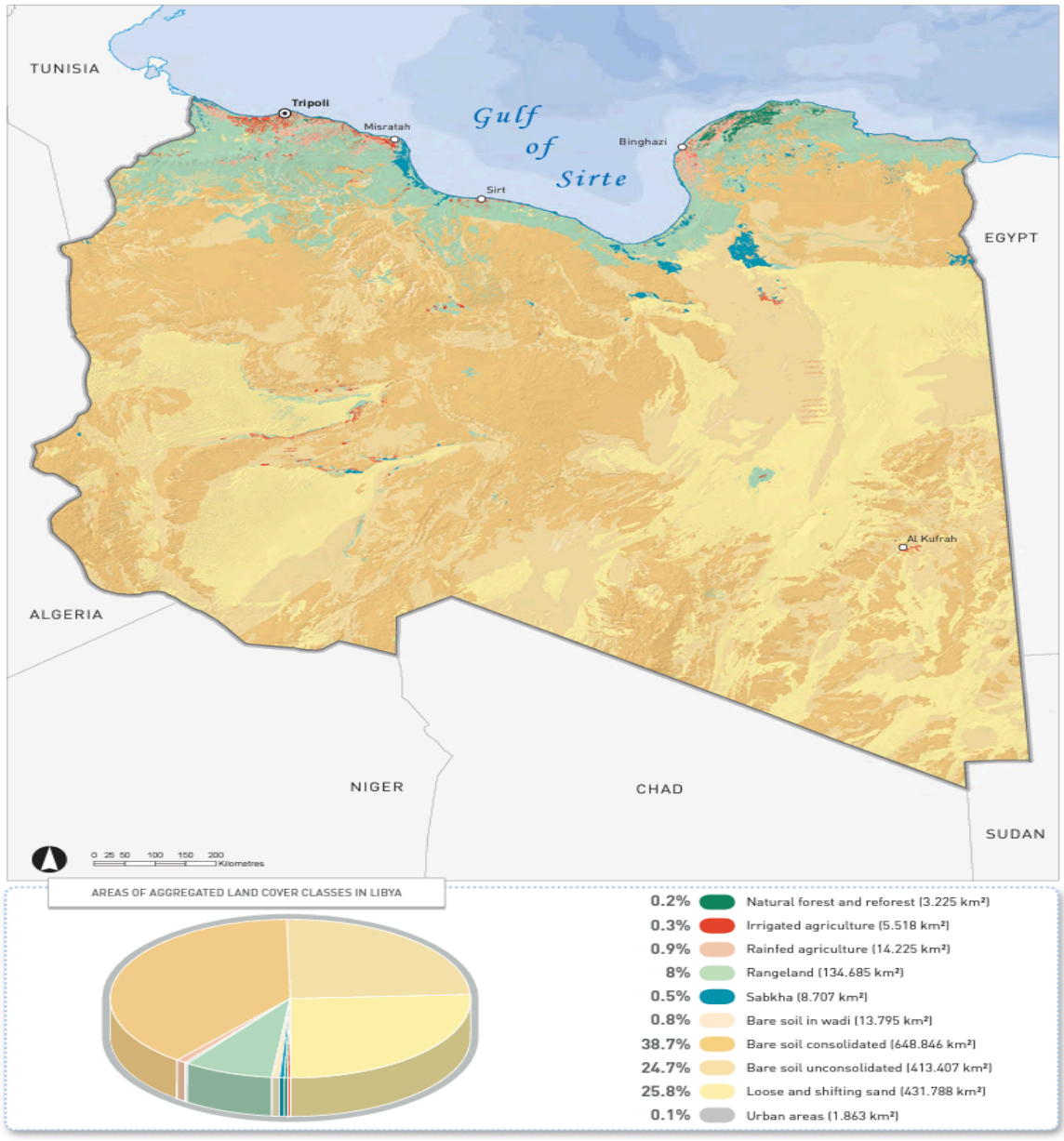
LCCS diagram



Appendix B – Existing land cover maps of Libya

Land over map of Libya 2009 produced by the FAO, which provides information on land cover types at a spatial resolution of 30 metres. The Libya land cover dataset has been carried out with a visual interpretation of satellite images covering the period (2001-2002). The 108 original land cover classes have been clustered into 10 generalized classes(FAO, 2009)

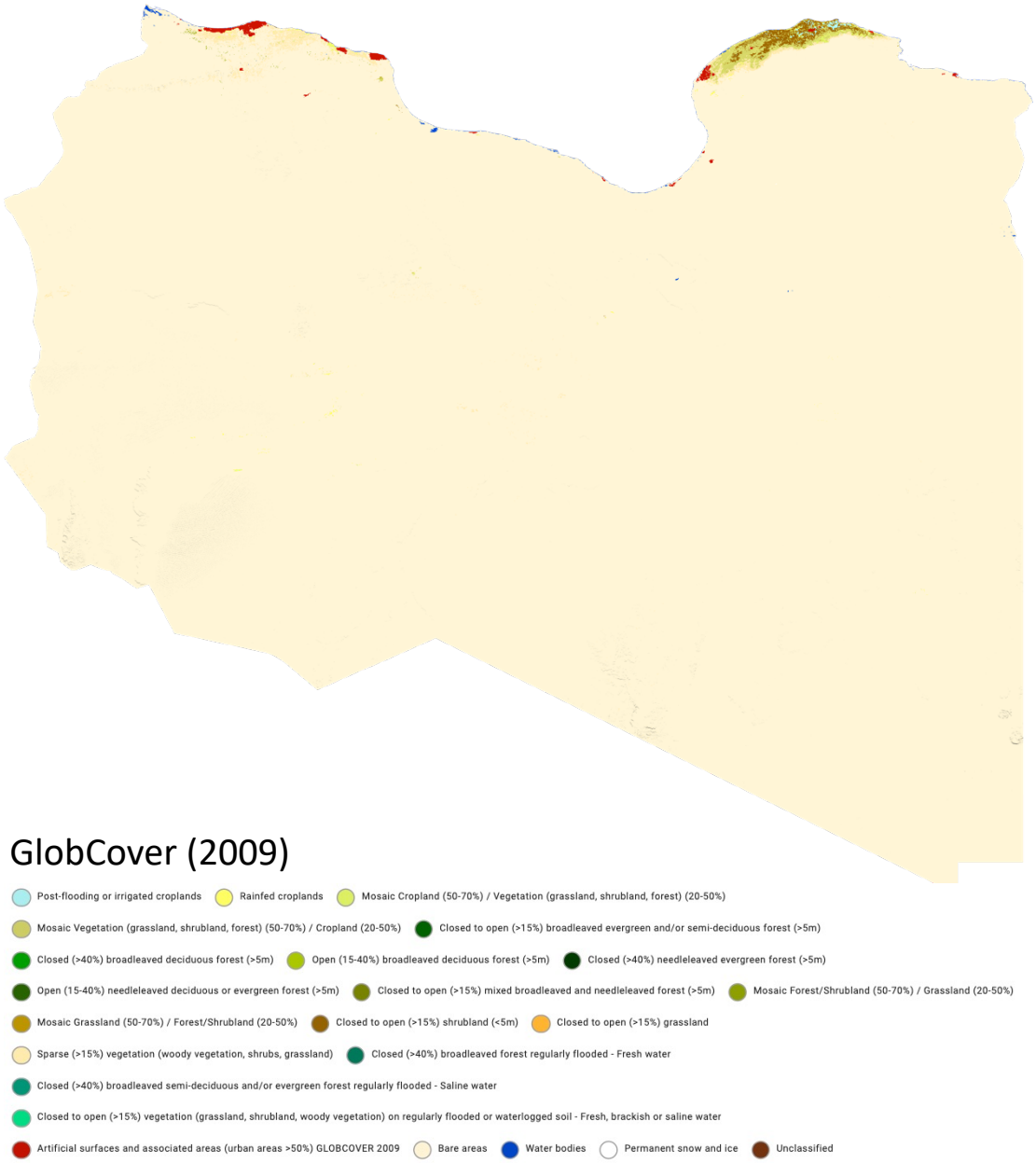
Figure B.1 land cover map of Libya in 2009 (Source: FAO 2009)



Source: Administrative boundaries HDX[shapefiles]. Cited 10 March 2023. https://data.humdata.org.

ESA GlobCover 2009 is a global land cover map based on ENVISAT's Medium Resolution Imaging Spectro metre (MERIS) Level 1B data acquired in full resolution mode with a spatial resolution of approximately 300 metres.

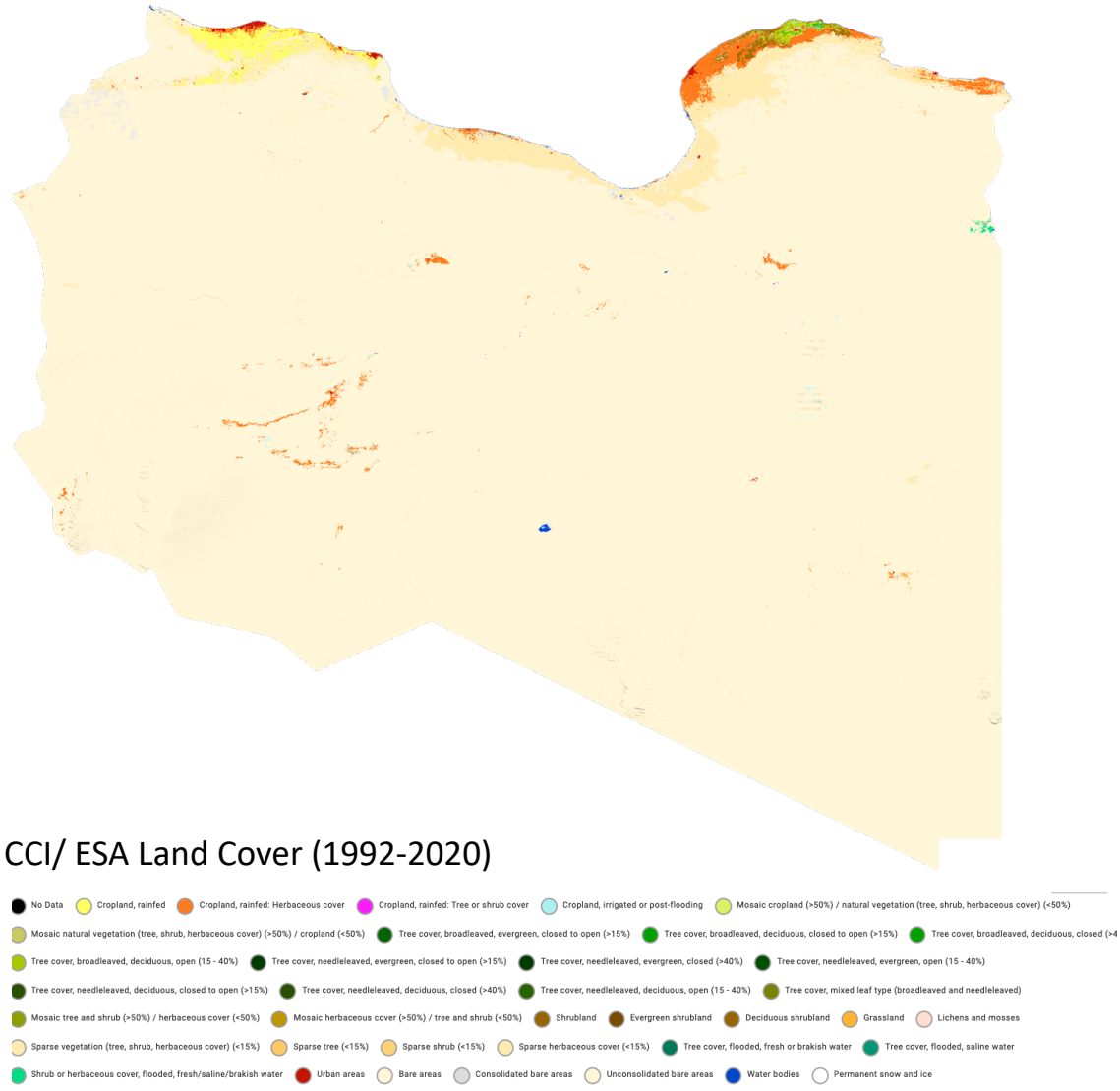
Figure B.2 land cover map of Libya in 2009 (Source: ESA GlobCover 2009 V2.3)



Source: Administrative boundaries HDX[shapefiles]. Cited 10 March 2023. https://data.humdata.org.

The CCI-LC project delivers consistent global land cover maps at 300 m spatial resolution on an annual basis from 1992 to 2020.

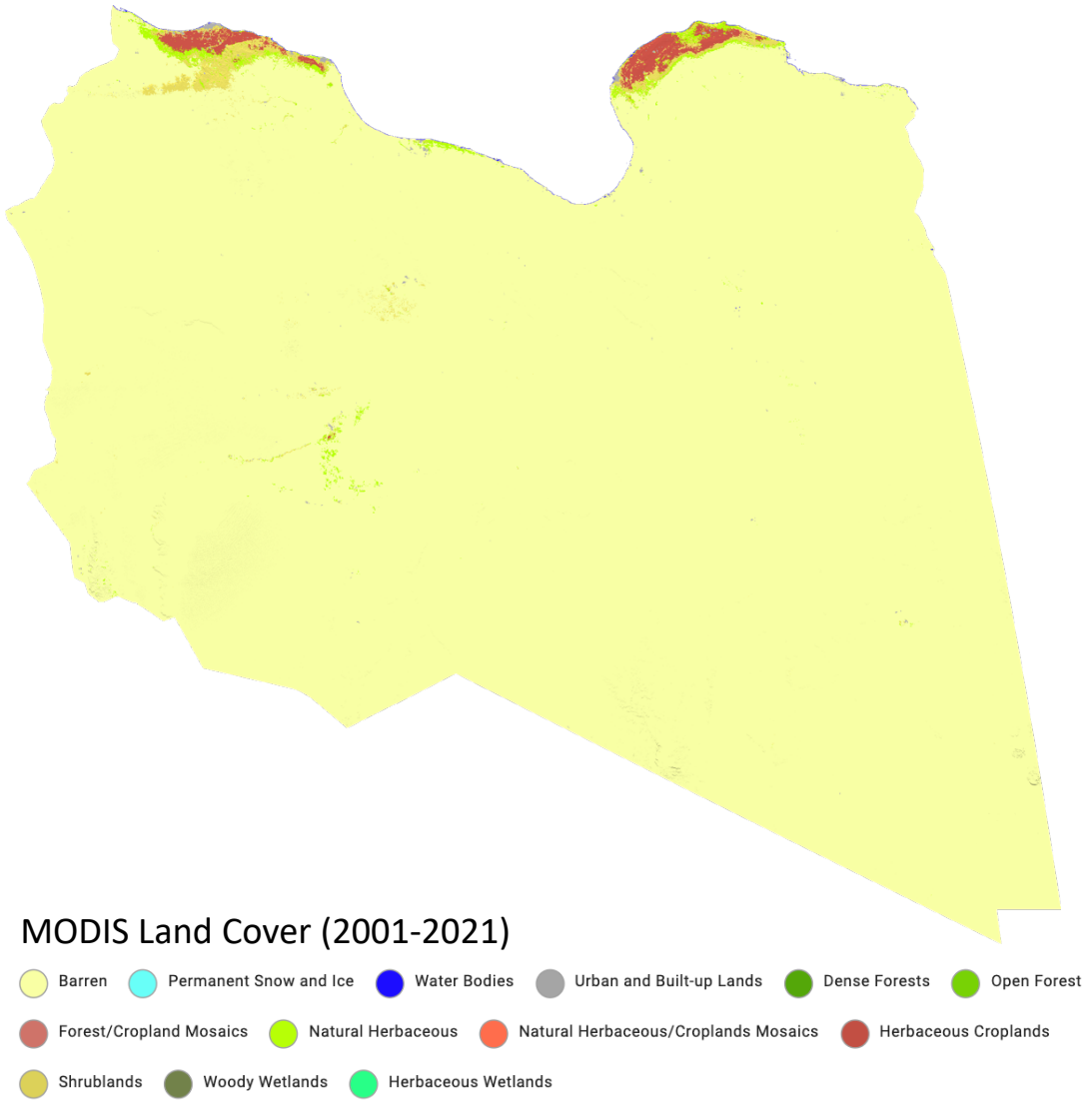
Figure B.3 land cover map of Libya in 2020 (Source: ESA land cover CCI v2.1.1)



Source: Administrative boundaries HDX[shapefiles]. Cited 10 March 2023. https://data.humdata.org.

The MODIS land cover type version 6.1 contains several datasets that map the global land cover at a spatial resolution of 500 metres with annual time steps. These datasets are produced from classifications of the Moderate Resolution Imaging Spectroradio metre (MODIS) Terra and Aqua reflectance data combined with post-processing correction based on prior knowledge. The data is available with a temporal resolution of one year and data is available from 2001 until 2021. This layer shows a combination of the land cover Classification System (LCCS) land use and hydrology classification (LCCS2 and LCCS3) created by the FAO according to the classifications of the SEEA. From the LCCS land use layer the areas classified as cropland are shown, while from the LCCS hydrology layer the woody and herbaceous wetlands are used when not classified as cropland in the land use layers. For areas not classified as either cropland or wetland the LCCS land use classification is used for a total of 13 land cover classes.

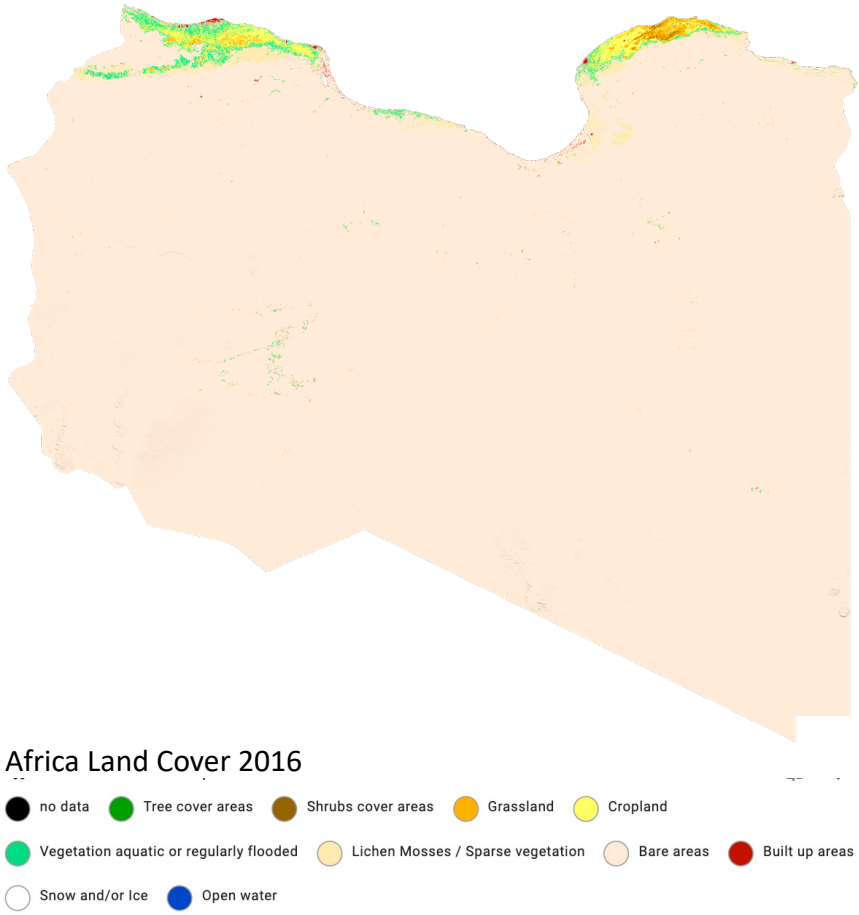
Figure B.4 land cover map of Libya in 2021 (Source: MCD12Q1.061 - MODIS land cover LCCS Land use and hydrology)



Source: Administrative boundaries HDX[shapefiles]. Cited 10 March 2023. https://data.humdata.org.

Prototype high resolution LC map at 20m over Africa based on 1 year of Sentinel-2A observations from December 2015 to December 2016. The legend of the S2 prototype LC 20m map of Africa 2016 was built after reviewing various existing typologies (e.g. LCCS, LCML…), global (e.g. GLC-share, GlobeLand30) and national experiences (Africover, SERVIR-RMCD). The legend includes 10 generic classes that appropriately describe the land surface at 20m: "trees cover areas", "shrubs cover areas", "grassland", "cropland", "vegetation aquatic or regularly flooded", "lichen and mosses / sparse vegetation", "bare areas", "built up areas", "snow and/or ice" and "open water". Two of the LC classes were largely identified thanks to external dataset: the "open water" class was based on the Global Surface Water product from JRC/EC and the "urban areas" relied both on the Global Human Settlement Layer from JRC/EC and on the Global Urban Footprint from DLR. Two classification algorithms, the Random Forest (RF) and Machine Learning (ML), were chosen to transform the cloud-free reflectance composites generated by the pre-processing module into a land cover map. The two maps resulting from both approaches are then combined either to select the best representation of a land cover class which will be part of the final S2 prototype LC 20m map of Africa 2016 or, in case of unreliable LC class delineation, the reference layer is used to consolidate the land cover classification.

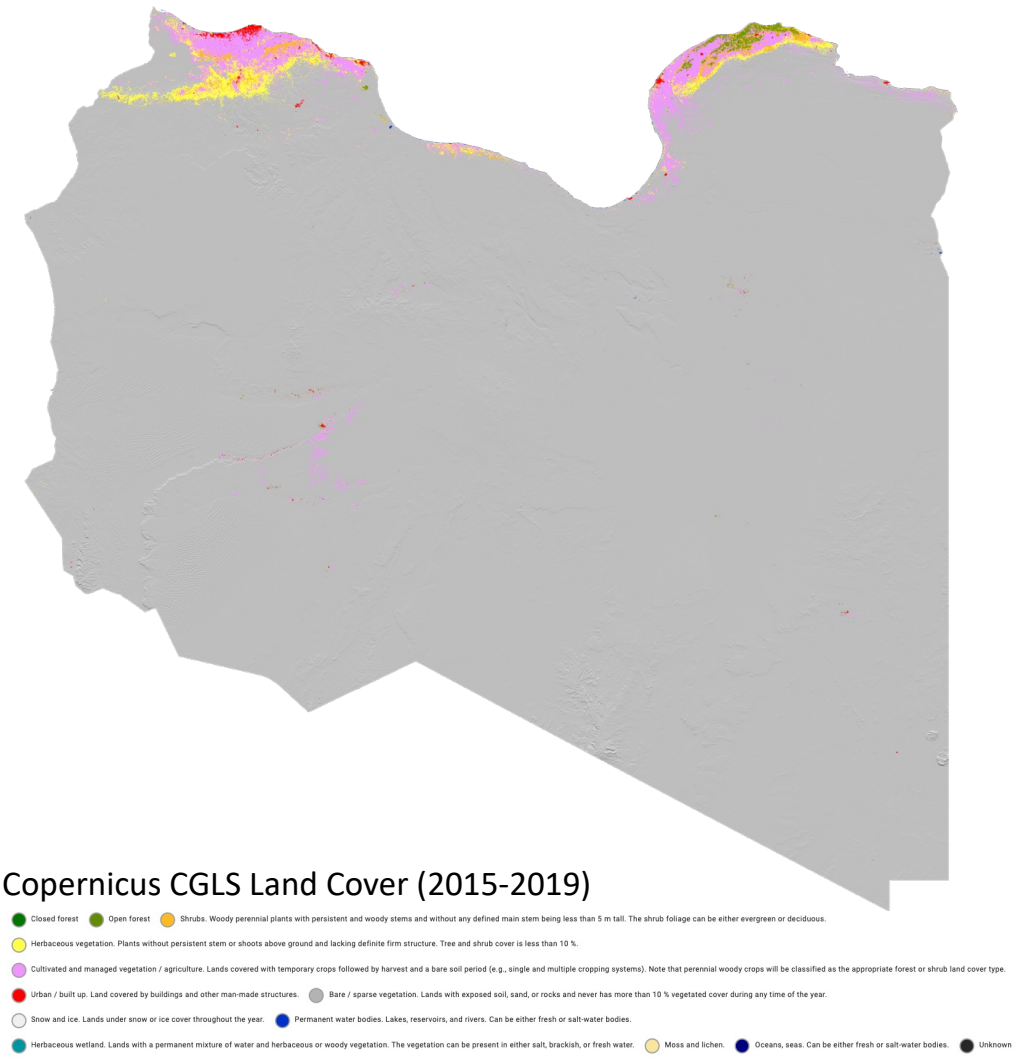
Figure B.5 land cover map of Libya in 2016 (Source: CCI land cover)



Source: Administrative boundaries HDX[shapefiles]. Cited 10 March 2023. https://data.humdata.org.

The Copernicus Global Land Service (CGLS) is earmarked as a component of the Land service to operate a multi-purpose service component that provides a series of bio-geophysical products on the status and evolution of land surface at global scale. The Dynamic land cover map at 100 m resolution (CGLS-LC100) is a new product in the portfolio of the CGLS and delivers a global land cover map at 100 m spatial resolution. The CGLS land cover product provides a primary land cover scheme. Next to these discrete classes, the product also includes continuous field layers for all basic land cover classes that provide proportional estimates for vegetation/ground cover for the land cover types. This continuous classification scheme may depict areas of heterogeneous land cover better than the standard classification scheme and, as such, can be tailored for application use (e.g. forest monitoring, crop monitoring, biodiversity and conservation, monitoring environment and security in Africa, climate modelling, etc.). This land cover map is provided for the 2015 reference year over the entire Globe, derived from the PROBA-V 100 m time-series, a database of high quality land cover training sites and several ancillary datasets, reaching an accuracy of 80 percent at Level 1.

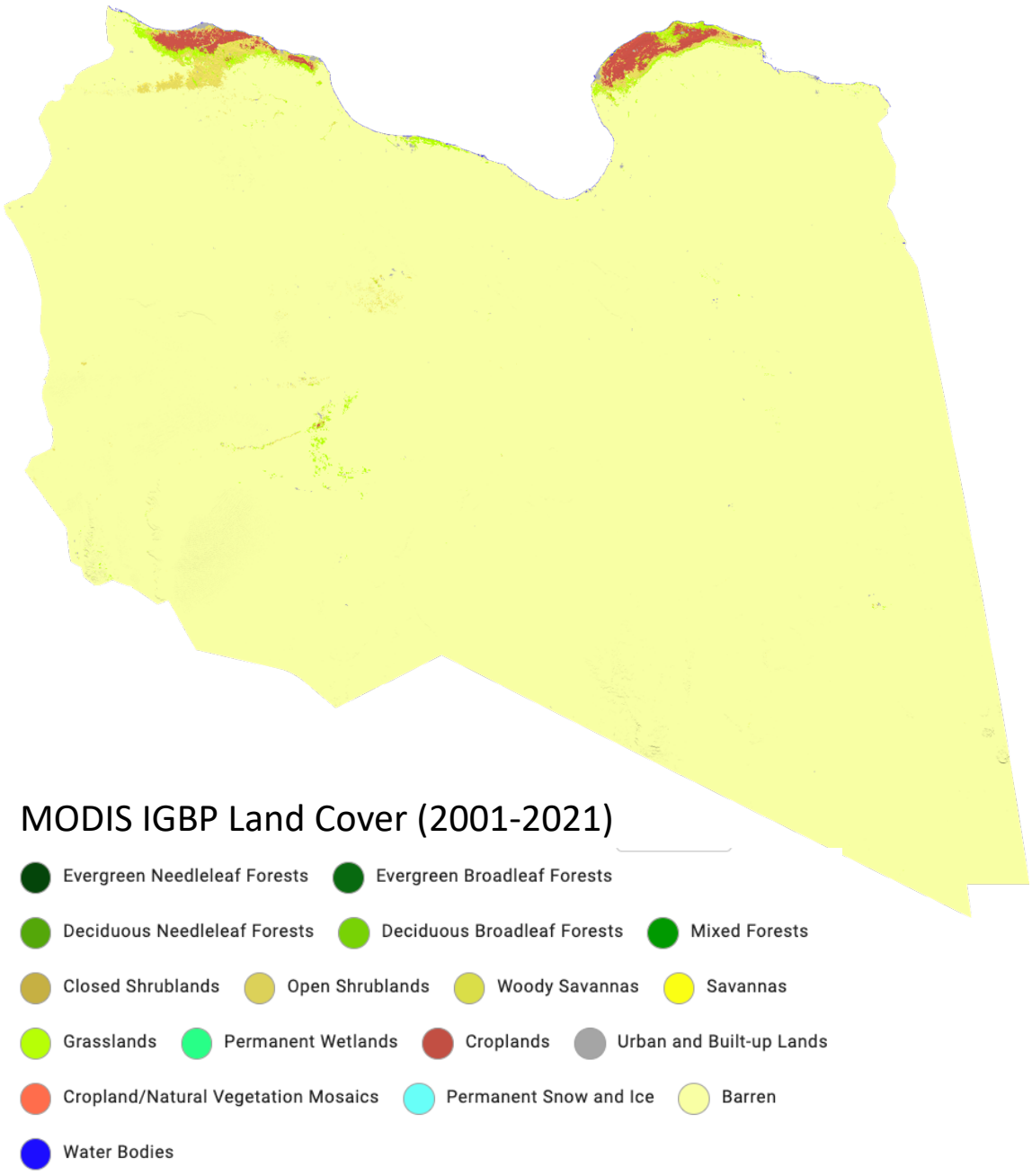
Figure B.6 land cover map of Libya in 2009 (Source: Copernicus Global land cover Layers: CGLS-LC100 collection 3)



Source: Administrative boundaries HDX[shapefiles]. Cited 10 March 2023. https://data.humdata.org.

The MODIS land cover type version 6.1 contains several datasets that map the global land cover at a spatial resolution of 500 metres with annual time steps. These datasets are produced from classifications of the Moderate Resolution Imaging Spectroradio metre (MODIS) Terra and Aqua reflectance data combined with post-processing correction based on prior knowledge. The data is available with a temporal resolution of one year and data is available from 2001 until 2021. This layer shows the International Geosphere-Biosphere Programme (IGBP) classification which consists of 17 land cover classes.

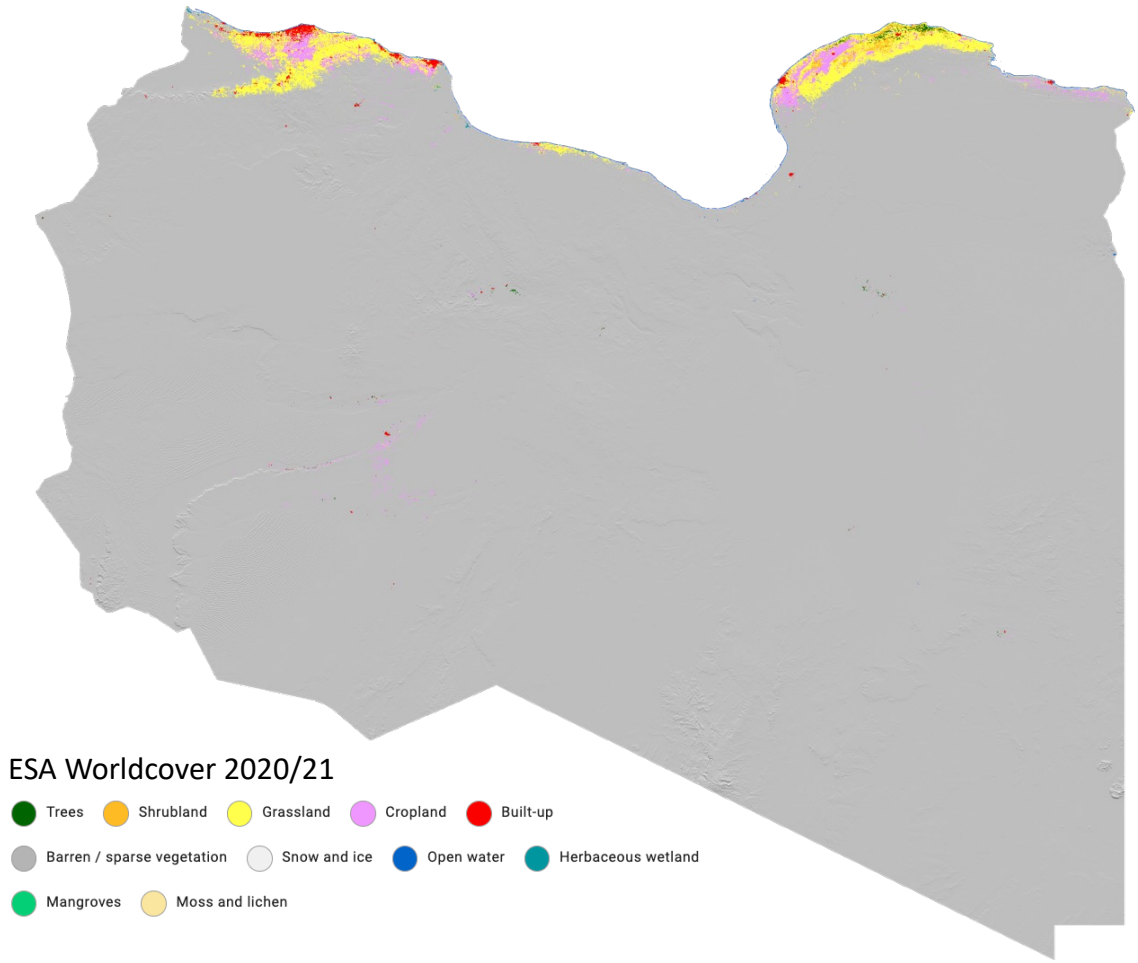
Figure B.7 land cover map of Libya in 2009 (Source: MCD12Q1.061 - MODIS land cover IGBP)



Source: Administrative boundaries HDX[shapefiles]. Cited 10 March 2023. https://data.humdata.org.

The European Space Agency (ESA) WorldCover 10 m product provides a global land cover map for 2020 and 2021 at 10 m resolution based on Sentinel-1 and Sentinel-2 data. The WorldCover product comes with 11 land cover classes and has been generated in the framework of the ESA WorldCover project, part of the 5th Earth Observation Envelope Programme (EOEP-5) of the European Space Agency. IMPORTANT : Since the WorldCover maps for 2020 and 2021 were generated with different algorithm versions (v100 and v200, respectively), changes between the maps include both changes in real land cover and changes due to the used algorithms.

Figure B.8 land cover map of Libya in 2009 (Source: European Space Agency (ESA) WorldCover 10m - 2020)



Source: Administrative boundaries HDX[shapefiles]. Cited 10 March 2023. https://data.humdata.org.

Appendix C - Using LCCS when deriving a legend from LCRS

Step 1 - .lccs regional file

Regional file in .lccs can be downloaded from FAO land cover legend registry (https://www.fao.org/hih-geospatial-platform/en/resources/land-cover-legend-registry/)

Step 2 - Download and install in LCCSv3 software into computer

This step describes how to download and install LCCSv3 step-by-step.

- ***Download step***

The overview of the main functionalities of the Land Cover Classification System software version 3 (LCCS3) version 1.8.0 Release (18.03.2015) and Java application can be found at: http://www.geovis.net/ .

Direct links for required software are below:

LCCSv3:

http://www.tngis.com/DownLoadGeoVIS/LCCS/Lccs3_Setup_183_2015_07_23.zip

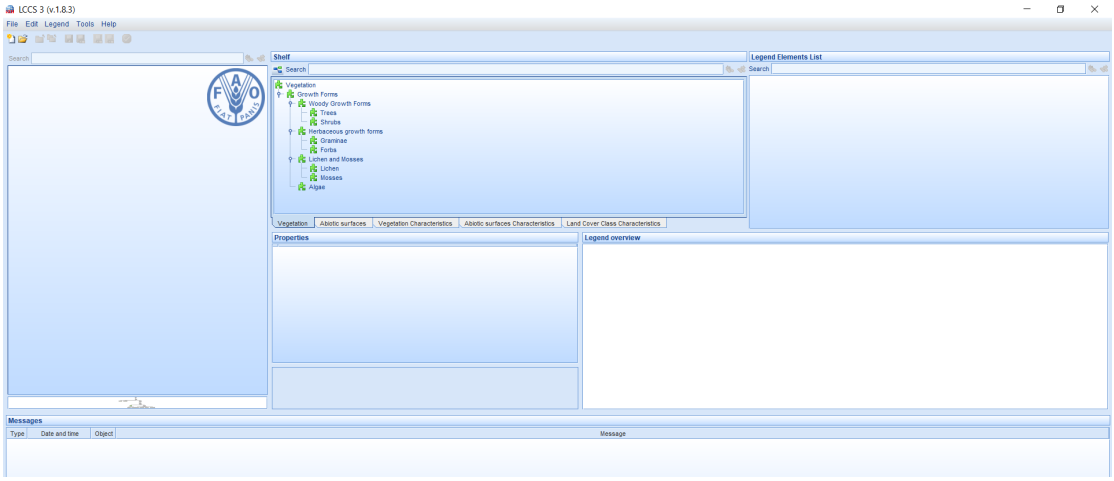
Java application:

http://www.tngis.com/DownLoadGeoVIS/Service/JRE-1_6_0_14-windows-i586-s.zip

- ***Installation step***

After downloading and uncompressing and installing the LCCS3 version 1.8.0 Release (18.03.2015) run it by clicking on the icon 

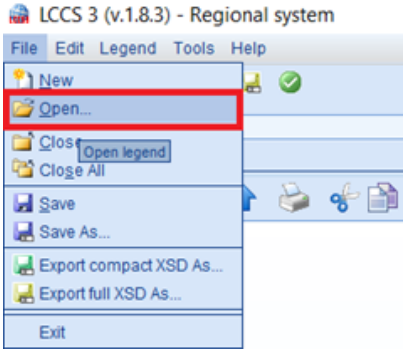
The application window will open, as shown below



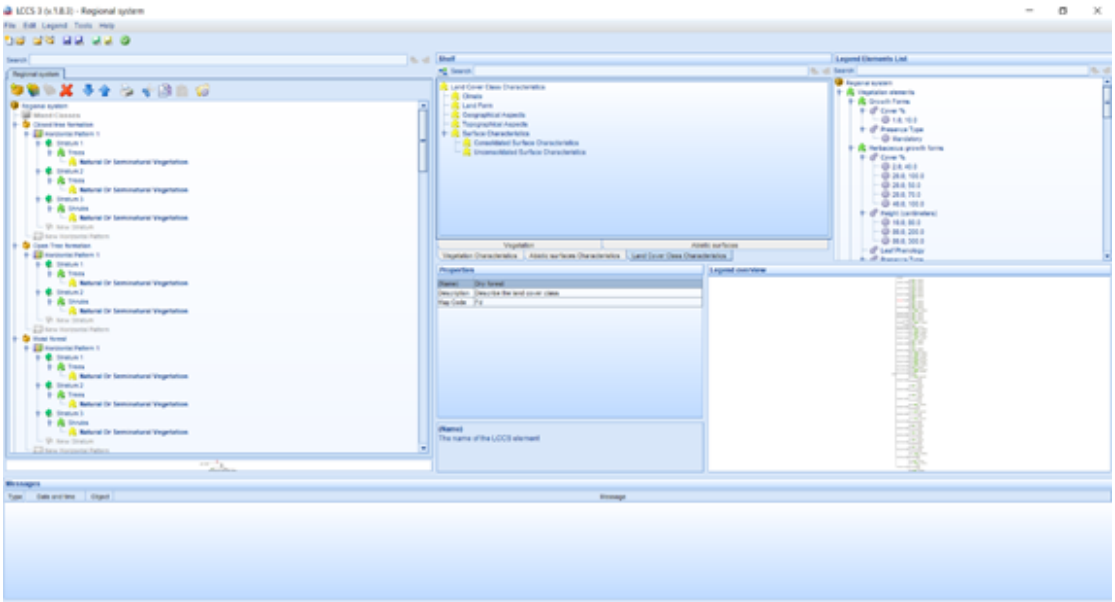
Step 3 – Loading .lccs regional file into LCCSv3 software

After installing LCCS 3 software and LCCS regional file, load file in the software and create/modify national or local legend:

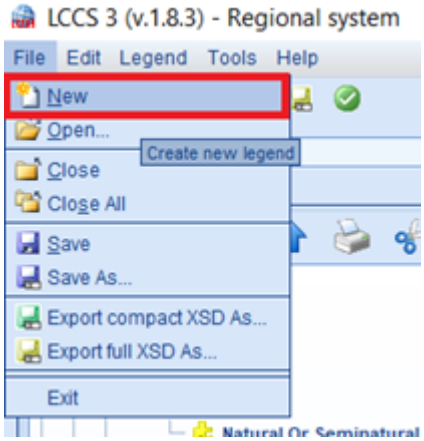
A. Open LCCS 3 software and click on file - > open (LCCS file: .lccs)



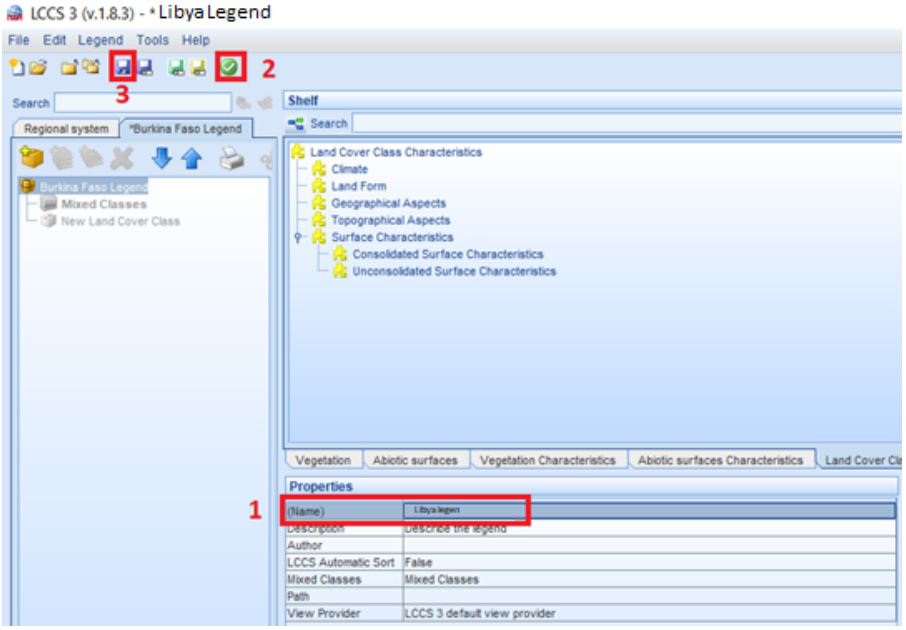
B. File will be open in software as seen below.



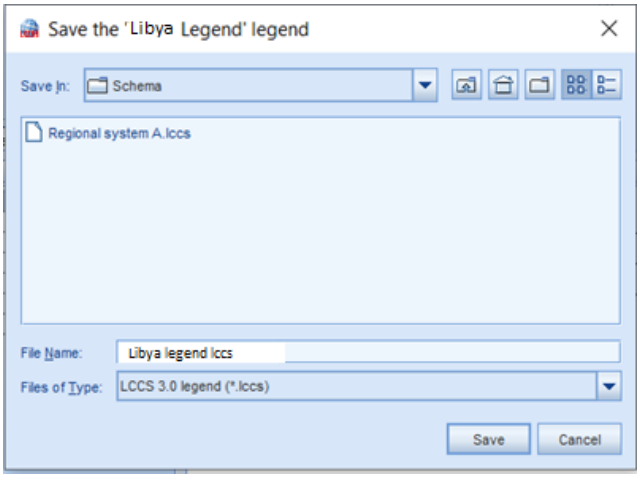
C. Now click on the file -> New



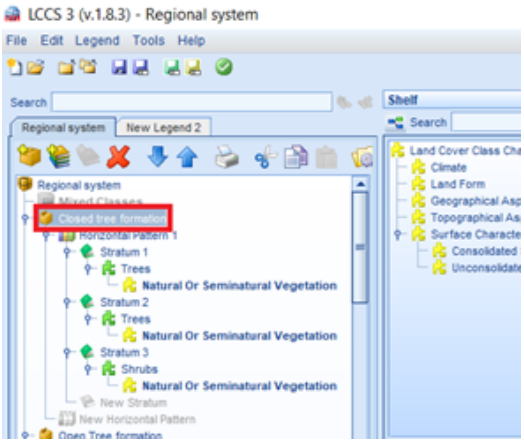
D. Edit name of the legend (1), validate (2) and save it in .lccs format (3).



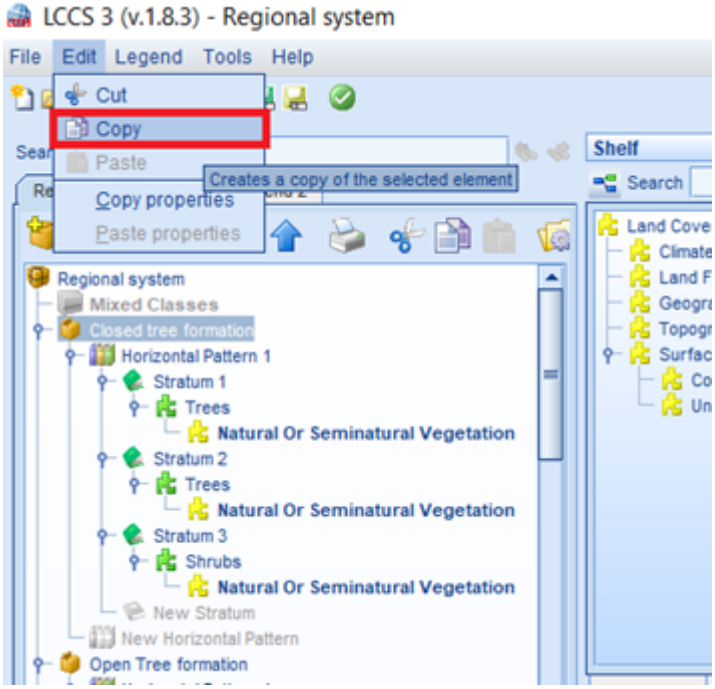
E. While saving a legend a new window will open. Give the folder path and click on save.



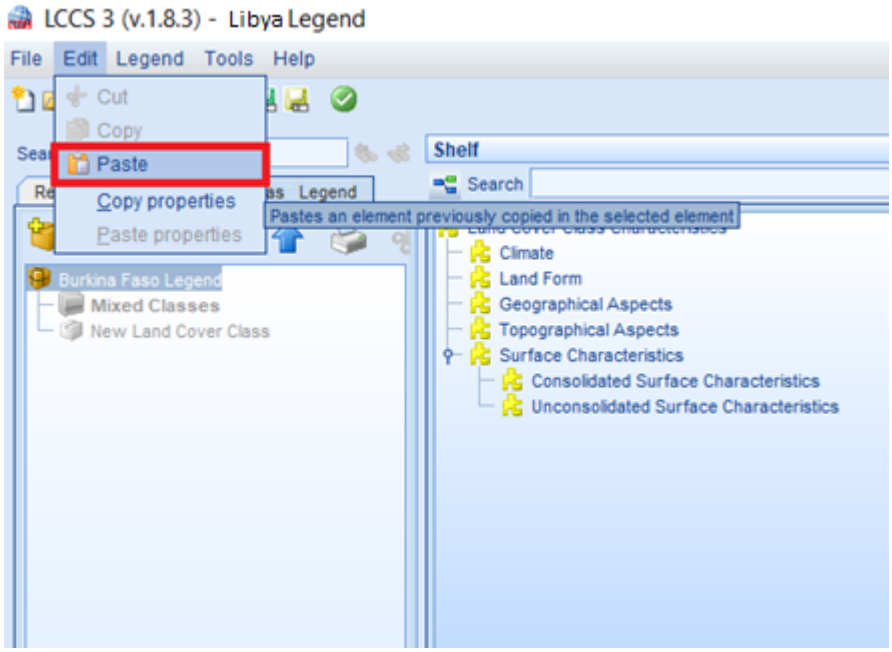
F. After saving a new legend, click on the regional file tab and select the required class.



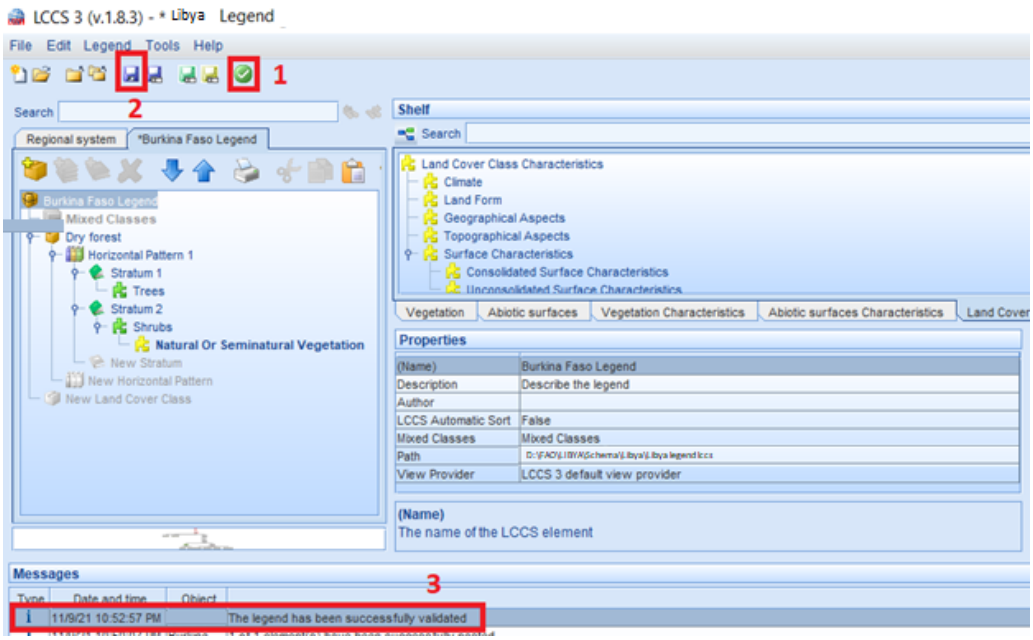
G. Click “edit” and copy selected class



H. Paste this class in a new file (named: “Libya Legend”). (Please be careful about the sequence of the classes while copying and pasting it in the new legend)

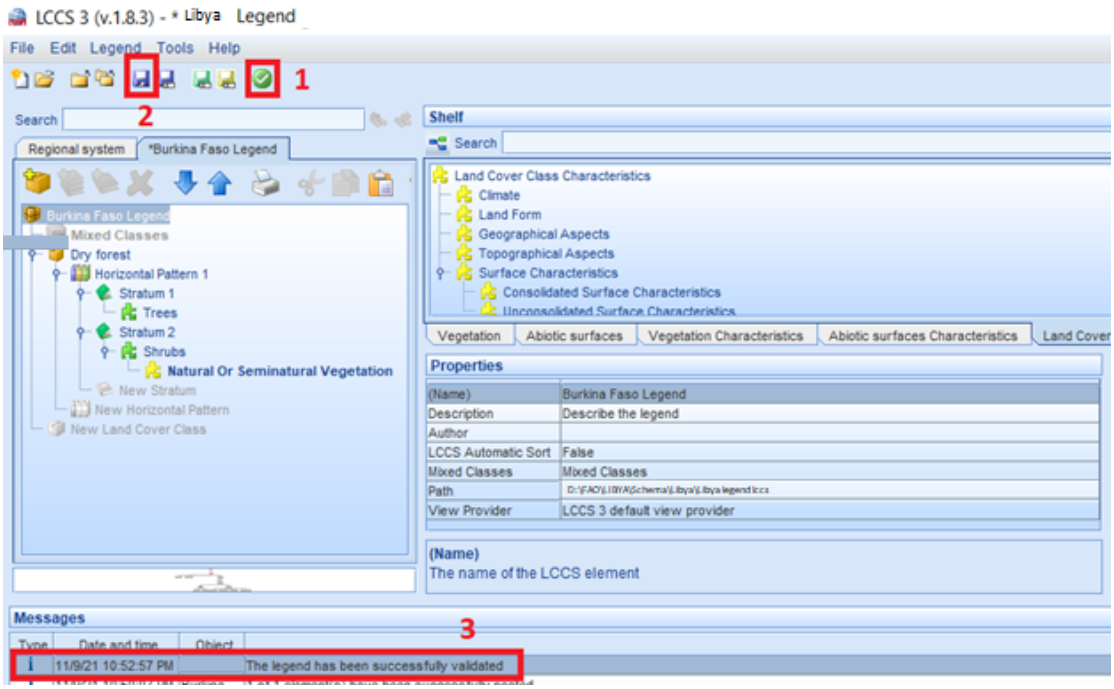


I. After pasting class in new legend file, edit map code if you want to change class attributes / additional detail to specific class



J. Users can add further details / features / attributes to a meta class.

K. Each time the user provides detail to the meta class, click on validate button (1). It will give notification in message section (3). In case of validation click on save button (2). Class will be updated and saved in given path.



For further detail please refer to the LCCS user manual document in the link below:

https://www.fao.org/3/i5428e/i5428e.pdf

IagWat
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