# **EAGLE Matrix Bar-Coding Manual**

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#### 13. Oktober 2023

Version 3.2

# **1** Scope of document

This manual is a guideline for the bar-coding method when using the EAGLE matrix. The aim of the barcoding is to transfer the information content of textual class definitions from a given classification system to a standardized ontological expression in terms of the EAGLE matrix. The elements of the EAGLE matrix allow class definitions to be semantically composed and de-composed. The resulting bar codes allow a sematic analysis and comparison between class definitions. When entered in a database, those results are also machine readable.

# 2 Reference Documents

For detailed explanation of the EAGLE matrix (and model) elements please refer to the Explanatory Documentation of the EAGLE concept under <u>https://clms-</u> <u>prod.eea.europa.eu/en/eagle?tab=document\_archive</u> "EAGLE-Concept\_ExplDocumentation\_revised\_v3.2\_20230922.pdf").

For the application of the bar-coding method, the EAGLE matrix in the latest version 3.2 shall be used. It is stored under <u>https://clms-prod.eea.europa.eu/en/eagle?tab=document\_archive</u>.

# 3 Structure of the EAGLE Matrix

### 3.1 Horizontal and vertical Matrix Form

The EAGLE matrix exists in two arrangements, a horizontal and a vertical arrangement, however the content of those two forms are identical.

Initially, in the horizontal form, each EAGLE matrix element is stored as one single table column, and several child elements are grouped under a parent element (several table cells unified into one field) on a higher hierarchical level.

The hierarchical levels go from top to bottom (expressed as table lines), and the number of columns is determined by the number of bottom level matrix elements, not counting the higher level elements because they appear as unified table cells.

In the vertical form of the matrix the EAGLE elements are arranged as table lines. The difference to the horizontal form is that every hierarchical level has its one table line, the parent as well as the child elements. This form still results in a fairly long table from top to bottom end. The hierarchical levels go from left to right (expressed as table columns), and the number of lines is determined by the number of bottom level elements plus every hierarchical parent level above them.

In the fictive case of 6 elements with a hierarchical structure of 2 parent elements, each of them heaving 3 child elements, the horizontal matrix has 6 columns and 2 lines (see Table 1), while the vertical matrix has 8 lines and 2 columns (see Table 2).

Table 1: Horizontal matrix form

Level 1		1.			2.	
Level 2	1.1	1.2	1.3	2.1	2.2	2.3

Table 2: Vertical matrix form

Level 1	Level 2
1.	
	1.1
	1.2
	1.3
2.	
	2.1
	2.2
	2.3

For illustration reasons and perspectives on logic context, we use here the horizontal matrix form. For the bar-coding exercise, the vertical form is proposed to be used.

The EAGLE Matrix is content-wisestructured in three main matrix blocks for Land Cover Components (LCC), Land Use Attributes (LUA) and further Land Characteristics (LCH).



**Figure 1:** Screenshot of the EAGLE matrix (total view in horizontal form) with the three blocks Land Cover Components (LCC), Land Use Attributes (LUA) and the Land Characteristics (LCH), in hierarchical order with parent and child (sub-ordered) elements.

Level	Land Cover Components																						
Lv1	ABIOTIC						BIOTIC										WATER						
Lv2	Artificial Na			Vatura	al		Woody			Herbaceous			Succu lents	L Moss	icher ses, A	i, Algae	Liq	uid	So	lid			
Lv3	Sealed Non-Sealed		Con da	isoli- ted	Cor	Un- Isolida	ated	Trees Bushes		Grass- Fo		Forbs Ferns		Lichens	Mosses	Algae	Inland	Marine	Snow	Ice			
Lv3	Specfic Structures Buildings	Open Sealed	Open Non-Sealed	Waste	Bare Rock	Hard Pan	Min. Fragments	Bare Soil	Nat. Deposits		Regular Bushes	Dwarf Shrubs	Grass, Cereals	Reeds, Bamboo						[]			

Level		Land Use Attributes																		
Lv1	Primary Secondary Production Production						Tertiary Production						ansp stic,L	Re	esider	ntl	[]			
Lv2	Agriculture	Forestry	Mining	Fishing	Industry	Manufacture,	Enerav Prod	Other Industry	Commercial	Financial, Information	Community Services	Cultural, Recreational	Other Services	Transport Netw.	Logistic, Storage	Utilities	Permanent Kesi			[]
Lv3				[]	[]	[ ]		:				[]	[]	[]		[]				
Level									Lar	id Ch	aract	eristi	cs		_					
Lv1	CI	Built harac	t-up teristio	cs	CI	Vege harac	tation terist	n ics		L	and M	Aanag	gemer	nt		Stat	us	Spa Patt	itial erns	]
Lv2	Soil Sealing Deg.	Built-up Pattern	Building Type	Surface Material	Leaf Form	Growth Form	Phenology	Crown Cover Dens.		Cult. Measures	Crop Type	Forest Practise	Mining Technique	Admin Regulation		Under Construction	Damaged	Heterogenous	Scattered	
Lv3	[]	÷	:	Ξ	:	·	÷	·		Ξ	[]	: <u> </u>	[]	[]						

**Figure 2:** Schematic illustration of the three EAGLE matrix blocks, normally all arranged side by side next to each other, here below each other with reduced level of detail.

### 3.2 Definition of terms and element types

In theory, the structure of the matrix and the "architecture" of the UML model allow the LCC to be combined with any kind of LUA or LCH. In practice however, the user has to be aware of the fact that not all combinations of matrix elements make sense. The architecture of the UML model takes this into account in a way that the various LCH are arranged as attributive attachments to the LCC elements (on different hierarchical levels) or to the overall LC Unit.

To find a common language when speaking about the EAGLE matrix, we suggest to use distinct expressions to address specific parts of the matrix.

- <u>Matrix block</u>: the three main blocks of the matrix which are the Land Cover Components, the Land Use Attributes and the Land Characteristics. These are the first entry points into the content of the

matrix structure. (see also Figure 2)

- <u>Matrix module</u>: a collection of matrix elements that refer to a certain topic or phenomenon (e.g., Status), or relating to a main Land Cover Component (e.g., Biotic / Vegetation Characteristics) or to a certain Land Use Type (e.g., Agricultural Land Management).
- <u>Matrix segment</u>: a section of a matrix module that contains a coherent group of elements under a thematic heading (e.g., Water Regime under the module Water Characteristics, or Cultivation Practice under the module Agricultural Land Management). The segments may be subdivided into subsegments (sub-headings).
- <u>Matrix element</u>: A neutral term to address each and any of all entries (LCCs, LUAs, LCHs) form the entire matrix (and model respectively) as an element. Matrix elements are all of the lowest and most important level of the LCH matrix block, where the single values are listed to store the characteristic information of an object in particular, plus all entries of the LCC and LUA on throughout the hierarchical levels.

Depending on the complexity of the matrix modules, they are subdivided into varying numbers of segments, sub-segments and elements. Therefore, the information carrier elements will not always be placed on the same hierarchical level throughout the entire matrix and the "depth" of the bottom level may vary from segment to segment.

In Block I. (LCC) and Block II. (LUA) all elements follow a hierarchical order and are subdivided into more detailed subtypes. No headings exist, every element can be chosen on every level to describe a land unit or a class definition (e.g., LCC level 1 vegetation, level 2 woody vegetation, level 3 trees) and LUAs (e.g. LUA level 1 Secondary Production Sector, level 2 Manufacturing Industry, level 3 Raw Industry, level 4 Manufacturing Textile Products ).

The III. LCH block also follows a hierarchical order, but is different in structure from LCC and LUA, as the higher level entries in the matrix are basically headings (modules), followed by sub-headings (segments), which can't be chosen to characterize a Land Unit, because they mainly give logical structure to the matrix elements, assembled by thematic fields with character instances below them. Therefore, the parent and most intermediate level entries do not function as an information carrier (e.g., the heading "spatial pattern" is not a descriptive term).

The most specific information is carried by the bottom level element (e.g., "mosaic spatial pattern") below the headings. In exceptional cases – e.g., in the LCH block and segment of crop types, also elements above the bottom level can be used as information carrier (e.g., LCH level 4 *Arable Crops*, level 5 *Cereals*, level 6 *Common Wheat*) to further characterize a given LCC or LUA.

# 4 Bar Code Method

### 4.1 Methodological Scope

For the bar-coding exercise, the vertical form of EAGLE matrix is used. The 'bar-coding' method is the procedure of selecting and assigning a value to relevant LCC, LUA and LCH elements from the matrix to describe a class. The bar-coding exercise results in a standardized and concise representation of a

semantically decomposed class definition using a sequence of numerical codes (where the inspiration for the term "bar code" comes from).

The EAGLE matrix elements initially have no specific bar code value (BCV) and are considered neutral. During the bar-coding exercise for a targeted class definition or landscape situation, these elements get assigned a certain BCV according to their importance and logical interrelationship within a given class definition. Thus, the matrix elements received their role in representing the content of a specific class definition. The resulting sequence of numerical codes assigned to the matrix elements serves as a descriptive summary of the class definition.

This bar-coding approach streamlines the process of representing complex information about different classes, making it easier to handle and to compare among them and with other classification systems. When working with the bar-coding exercise, different classes require the EAGLE elements to take different roles, according to the targeted definitions. Similar class definitions should be reflected in similar bar-coding results.

### 4.2 Bar Code Value List

In the bar coding approach, matrix elements can perceive different roles and have different relations to each other. Those relations are expressed with semantic operators, which are coded with alphanumerical digits/letters, called Bar Code Values (BCV). Table 3 shows the list of BCVs followed by short explaining paragraphs for each code.

**Table 3:** List of Bar-code value meanings. The BCVs define the role of EAGLE elements torepresent a given mapping rule, class definition or landscape situation.

Bar-code Value (BCV) table										
Value	Description									
Х	Element is excluded by definition									
1	Optional element, it can occur as typical but is not mandatory									
2	Selective mandatory element, EITHER-OR logic, at least one or more of all elements with assigned BCV 2 must be present									
3	Cumulative mandatory element, AND-logic, all elements with assigned BCV 3 must be present									
4	Paired mandatory element, at least two of all elements with assigned BCV 4 must be present									
5	Exclusive mandatory element, NOTHING-BUT-logic, practically allows only the one element with assigned BCV 5 and excludes any other element from its parent matrix block									

*x*: This matrix element must not be present, because it is explicitly excluded by definition from the class content.

1: This matrix element is mentioned in the class definition as an optional element. It can be expected in the class and can occur occasionally. Its presence can be typical but still not a compulsory element of the class. These elements may be mentioned in the class definition as examples (in a nonexhaustive list), which may occur along with other mandatory elements. The scale and the applied minimum mapping unit of the class has to be taken into account for this bar code value.

- 2: This matrix element is mentioned explicitly in the class definition as a defining element. It is a selective mandatory element with an EITHER-OR-relation to other elements with the same coded value. It means that at least one of these elements must be present in the land unit assigned to this class. Also, several of these elements can occur. This bar code shall not stand alone, once an element is assigned to BCV 2, there should always be at least one (or more) co-related elements with BCV 2.
- **3**: This matrix element is mentioned explicitly in the class definition as a compulsory element. It is a cumulative mandatory element with an AND-relation to other defining mandatory elements. It means that ALL of the value 3-coded elements must be present in the land unit assigned to this class. Normally, more than one element with BCV 3 should be expected (because of its AND-meaning) along with other mandatory elements. However, when there is just one compulsory element mentioned in the definition, BCV 3 can also stand-alone (without having the killing effect like BCV 5 has).
- **4**: These matrix elements are mentioned explicitly in the class definition. They belong to a group of paired defining mandatory element of the class. Such value 4-coded elements cannot occur as standalone elements. They are alternatively combined mandatory elements with EITHER-AND-OR-relation. It means that at least two or more (but not necessarily all) out of the group of elements marked with this code must be present.

(Example: The presence of EITHER [grassland AND arable land], OR [grassland AND permanent crops], OR [arable land AND permanent crops], OR ALL of them lead to the assigning of CLC class 242 complex cultivation pattern.)

**5**: This matrix element is mentioned in the class definition as the exclusive mandatory element. For the decomposed class definition it is the only valid and relevant element. The BCV of 5 can only be assigned once per matrix block, it kills all other elements. It expresses an ONLY-THIS-ONE-relation to other matrix elements.

### 4.3 Working Steps

#### Step 1:

When working directly with the Excel form of the EAGLE matrix template, enter the name of the targeted classes as a new column heading in the matrix beside (right side) of the list of EAGLE elements.

#### Step 2:

Identify terms and expressions in the class definitions that are addressing the themes land cover and land use as well as indicators for further characteristics like parameters, thresholds, patterns, management types, status etc.

#### Step 3:

Identify the relevant matrix elements of the LCC, LUA and LCH blocks that match to the extracted information of class definitions from Step 2.

#### Step 4:

Fill in the matrix cells down the class column for the entire class being described by using the bar code

values and assigning them to the elements. The bar code values reflect the role and significance (mandatory, optional, excluded by definition etc.) of the chosen elements and the relation between elements. For the precise meaning of the bar codes see Table 3.

The Excel sheet has pre-formatted rules which give a different color for each of the entered bar code values (X black, 1 blue, 2 orange, 3 red, 4 purple, 5 green).

## 4.4 Procedural Instructions

### 4.4.1 Explicit versus interpreted mapping rules

The information used as input to the bar-coding can potentially have two sources. The first is the textual definition of class from the nomenclature guidelines. The second is how those definitions are applied for mapping real-world object where sometimes the class definitions are interpreted more broadly and where some more land aspects are included in the class beside what is explicitly mentioned in the textual class definition. For a bar-coding exercise, only be the explicitly textual content of class definitions should be used. They should not be interpreted as far as possible; assumptions about what else might occur in land units of the assigned classes should be avoided.

Also, when it appears that in reality certain class definitions have been extended during mapping initiatives and some features are included (as a soft and unwritten rule) in the class, it should not have an impacton the bar-coding result.

If it is otherwise (going beyond the strict textual definition) it must be clearly stated and documented to what extent a class definition has been broadened as input for a bar-coding exercise. (The consequence of a more open and broader bar-coding can and should result in an adaption of the nomenclature's original class definition.)

#### Instruction 1:

Only explicit textual definitions and terms should be used as input for bar-coding exercise.

When looking for descriptive information in the class definitions, one should rely primarily on elements that are explicitly mentioned in the text. The class names and definitions shall not be interpreted from the user's perspective unless it would lead to obvious logic inconsistency or lack of crucial elements.

#### Example:

A class is called "artificial urban fabric". The reader interprets, that there must be buildings in that class. Also, in urban areas most probably there are residential areas. This may logically be correct. However, neither the term "buildings" nor "residential use" is mentioned explicitly in the definition/name. In consequence, LCC "Buildings" shall not be chosen for bar-coding, but only the upper level LCC "Sealed Artificial Surfaces and Constructions" and no distinct information about residential use shall be coded.

#### Another example:

Arable land in the area of a semi-arid climate zone is most likely to be artificially irrigated, probably also fertilized to a certain extend. However, if not mentioned in the definition, this kind of cultivation measure should not be given a BCV in the matrix.

Naturally, the terminology on LCC, LUA and LCH in the text can be slightly different from the matrix terminology, therefore it is acceptale to look out for synonyms. The important point here is that the

meaning of an expression found in the class definition can clearly be related to the meaning of a matrix element. In case of uncertainty the matrix element definitions can be checked in the Explanatory Documentation, listed above under chapter 2 Reference Documents.

### 4.4.2 Effect range of bar code relations within matrix

The Bar Code Values express not only an importance or role of the coded element for a decomposed targeted class, they also express the relationship between the chosen matrix elements. Therefore, it needs to be clarified, to what extent or range such relation have their "effect" on other parts of the matrix.

For the LCC, the effect range of the bar code values (AND/OR-functions) should be understood within the entire LCC matrix block.

Also, for the LUA block it is a similar setting, the bar code values relations range within the borders of the entire LUA block.

For the Land Characteristics matrix block the setting is different, because several characteristics from different segments can apply the same way for a LCC or also for a LUA. This is for example the case with the cultivation measures, that are not just mutually exclusive once attached to a LCC or LUA. They can be combined with other characters like spatial patterns, status, ecosystem types, etc. For the LCH matrix block the selective mandatory code value 2 (mandatory 'OR'-function) should be understood within major segments of LCH. The hierarchical structure of the LCH block is differs within itself and has a varying depth, on the same hierarchical level both a subtype heading or a character can be found. An orientation for the effective range of a bar code's meaning among matrix elements can be the LCH segment heading (parent entry) above the subtype (child) elements.

#### Instruction 2: effective range of Bar code values:

BCV X: across matrix

BCV 1: across matrix block

BCV 2: within matrix segment (when several coded element within segment) and across matrix

BCV 3: across matrix

BCV 4: across matrix

BCV 5: across matrix block

### 4.4.3 Comprehensiveness of Bar-Coding

In general, it is recommended to work with all possible elements (mandatory as well as optional elements) which are mentioned in a class definition. This will help to understand the semantics of uploaded and decomposed data.

This recommendation is also legit fFor the ingestion procedure on the CLC+ Core platform (hosted by EEA). On the extraction side of CLC+ Core System, it is probably more viable to work only with the mandatory elements, to get tangible results. However, also here the spatial distribution of optional elements could be of interest to get a database response.

# **5** Application Examples for Matrix Elements

Some examples of the matrix application for combination of LCC, LUA, and LCH to describe real landscape unit scenarios are:

- Parcel of woodland that has been partially damaged by storm:
  LCC: *Trees*;
  LUA: *Forestry*;
  LCH1: *Leaf Form = needle leaved*; LCH2: *Foliage Persistence = evergreen*. LCH3: *Status | Damage Reason = tornados, hurricanes, strong winds*
- Abandoned industrial site: LCC: specific structures and facilities; LUA: Raw industrial; LCH: Status | abandoned
- Intertidal flat: LCC1: clay, silt; LCC2: sand; LCC3: Marine Waters; LUA: not relevant; LCH1: (Bio)-Physical characteristics | Water Characteristics | Tidal Influence = yes; LCH2: (Bio)-Physical Characteristics | Water Characteristics | Salinity = saline
- Rural village settlement (see Figure 3): LCC1: Buildings; LCC2: open sealed surfaces; LCC3: Biotic/Vegetation; LUA1: permanent residential; LUA2: Agriculture | production for own consumption; LCH: Spatial Patterns |Built-up Pattern = scattered single houses, discontinuous.



Figure 3: Example for a rural village. Photo copyright: George Büttner

 Inland wetland (see Figure 4): LCC1: standing water, LCC2: reeds, bamboos and canes; LUA: natural areas not in economic use; LCH1: Ecosystem Types = inland marshes; LCH2: Salinity (Water or Soil) = fresh water



Figure 4: Neusiedler See, Austria. Photo copyright: Barbara Kosztra

 Scandinavian heathland (see Figure 5): LCC1: dwarf shrubs, LCC2: Mineral Fragments = boulders, stones; LCC3: Lichens, Mosses and Algae; LUA: no economic use; LCH1: Ecosystem Types = Heathland, shrub and tundra



Figure 5: Alpine Calluna heath, border between NO and SE. Photo copyright: Norwegian Forest and Landscape Institute.

 Golf course (see Figure 6): LCC1: trees, LCC2: graminoids, LCC3: standing water; LCC4: Mineral Fragments = Sand LUA: Sports Infrastructure | golf course; LCH1: Spatial Distribution Patterns = mosaic, LCH2: Mowing + LCH3: recurrent frequency = weekly.



Figure 6: Example for a golf course. Source: http://www.bilyanagolf.com/gloria\_golf\_club\_old\_course.php

 Arable crop land (see Figure 7): LCC1: Graminoids, LCC2: trees; LUA: Commercial agricultural crop production; LCH1: Crop Types = wheat; LCH2: Spatial Distribution Patterns = mosaic; LCH3: Cultivation Measures | Irrigation Method = sprinkler (e.g.); LCH4: Cultivation Measures | FertilizatingType = unknown, LCH5: Linear Landscape Patterns = rows of trees



Figure 7: Wheat fields with rows of trees. Foto copyright: George Büttner

# 6 Bar-Coding Exercise Examples

Below are two examples on the bar-coding decomposition, showing only the EAGLE elements from the matrix which have been assigned to each targeted situation, one from an existing landscape type (Figure 8) and two nothers from a given textual class definition (Figure 9 and Figure 10).

	EAGLE MATRIX									
	Element Code	Element Label	hierach. Level -	Bar Code Value 🖵						
	LCC-1_1_1_2	Specific Structures and Facilities	4	3						
	LCC-2_2	Herbaceous Vegetation	2	3						
	LUA-1_1	Agriculture	2	3						
	LUA-2_2_4_2	Solar Based Energy Production	4	3						
	LUA-2_2_4_3	Wind Based Energy Production	4	3						
A A A A A A A A A A A A A A A A A A A	LCH-5_1_1_2	Managed Permanent Grassland	4	3						
a star a faith a star and a star	LCH-5_1_4_8_2	Mowing Applied	5	2						
	LCH-5_1_4_9_2	Grazing Present	5	2						

**Figure 8:** Example how to decompose and bar-code a complex landscape situation: Pasture grassland combined with Renewable Energy Production. All elements assigned code "3" are <u>cumulative</u> mandatory and must all be present. Elements coded with "2" are <u>selective</u> mandatory meaning at least one of them present. must (more can) be present.

Class Definition 3.2.1 Natural grassland		EAGLE MATRIX		
Grasslands under no or moderate human	Element Code	Element Label	hierach. Leve <sup>i</sup>	Bar Code Value
frequently including rocky areas or patches of	LCC-1_2_1_1	Bare Rock	4	1
ather (comi ) natural wagetation Natural	LCC-1_2_2_1	Mineral Fragments	4	1
other (semi-)natural vegetation. Natural	LCC-2_1_1	Trees	3	1
grasslands are areas with herbaceous	LCC-2_1_2	Bushes, Shrubs	3	1
vegetation [].	LCC-2_2_1	Graminoids, Grass-Like	3	3
Besides, areas of shrub formations, of scattered	LCC-2_4	Lichens, Mosses, Algae	2	1
trees and of mineral outcrops also occur. Often	LCH-5_1_4_1_2	Ploughing Applied	5	X
under nature conservation. In this context	LCH-5_1_4_2_2	Fertilization Applied	5	X
"natural" indicates a minimum human	LCH-5_1_4_4_2	Pest Control Applied	5	X
interference, (not drained, irrigated, sown,	LCH-5_1_4_5_2	Irrigation Applied	5	X
fertilized) [ ]	LCH-5_1_4_7_2	Drainage Applied	5	X
Maintenance mowing and shrub clearance for	LCH-5_1_4_9_3	Extensive, Freerange Grazing	5	1
provention of woody overgrowth due to natural	LCH-5_1_4_11	Shrub Clearance	4	1
prevention of woody overgrowth due to hatural	LCH-5_5_2_1	Nature Conservation Area	4	1
succession is tolerated. []	LCH-8_1_4	Scattered	3	1

**Figure 9:** Example of bar-coding decomposition of the textual CLC class definition "Natural Grassland". Mandatory elements are coded with "3", typical but optional elements are coded with "1", and elements excluded by definition are coded "X".

Agricultural:	Code	Label	hierarch. Level	Bar Code Value
Arable Land [Urban Atlas]	LCC-1_2_2_2	Bare Soils	4	2
	LCC-2_1	Woody Vegetation	2	1
Fields under rotation system	LCC-2_2	Herbaceous Vegetation	2	2
Con be non irrigated or permanently	LCC-3_1_1_2	Standing Water	4	2
Can be non-imgated or permanently	LUA-1_1_1	Commercial Crop Production	3	5
irrigated.	LCH-5_1_1_1	Arable Crop Land	5	3
Also includes rice fields.	LCH-5_1_2_1	Crop Rotation	4	3
Fields laid in fallow are included	LCH-5_1_2_9	Paddy Field Cultivation	4	2
Tields laid in fallow are included.	LCH-5_1_4_5_1	No Irrigation	5	2
	LCH-5_1_4_5_2	Irrigation Applied, Method Unspecified	5	2
	LCH-5_1_6_1	Arable Crops	4	3

**Figure 10:** Example of bar-coding decomposition of the textual CLC class definition "Arable Land" from the CLMS Product Nomenclature "Urban Atlas". (Agricultural) Commercial Crop Production with BCV "5" (excludes all other LUA). In this case, rice fields are included in the class, in contrast to other nomenclatures (like e.g., CLC). Some Land Cover Components are also assigned to a bar code, even though not explicitly mentioned in class definition, in favor of logic consistency.