ECMWF COPERNICUS REPORT

Copernicus Climate Change Service

Tutorial

CDR Land Cover (brokered from CCI Land Cover)

Issued by: BC/ Carsten Brockmann

Date: 30/11/2018

Ref: D4.3.3-Tutorial_CDR_LC-CCI_v2.0.7cds_Products_v1.0.1

Official reference number service contract: 2018/C3S-312b-Lot5_VITO/SC1

IMPLEMENTED BY ECMWF

Contributors

BROCKMANN CONSULT GMBH
Brockmann, Carsten
Boettcher, Martin
Kirches, Grit

History of modifications

Version	Date	Description of modification	Chapters / Sections
V1.0	31/08/2018	First version	All
V1.0.1	30/11/2018	Update regarding the RIDs	Document reference and file name have been changed
V1.0.1	30/11/2018	Update regarding the RIDs	References have been updated
V1.0.1	30/11/2018	Update regarding the RIDs	Section - Executive summary - has been updated
V1.0.1	30/11/2018	Update regarding the RIDs	Section 1 has been significantly shortened
V1.0.1	30/11/2018	Update regarding the RIDs	Section 2 has been updated
V1.0.1	30/11/2018	Update regarding the RIDs	Section 3 has been rephrased

Related documents

Reference ID	Document
D1	ESA LAND COVER CCI – Land Cover CCI PRODUCT SPECIFICATION DOCUMENT -YEAR 2 VERSION 1.3 - CCI-Land Cover-PSDv2 - D1.2 - V1.3 - 2016-06-15 available online at https://www.esa-landcover-cci.org/?q=webfm_send/111 accessed on 2018/08/28
D2	ESA LAND COVER CCI – PRODUCT USER GUIDE - VERSION 2.0 - CCI-Land Cover-PUGV2 - D 3.3 - V2.0 - 2017/04/10 available online at http://maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-Land Cover-Ph2-PUGv2_2.0.pdf accessed on 2018/08/28
D3	ESA LAND COVER CCI – PRODUCT USER GUIDE - VERSION 1.1 - CCI-Land Cover-PUGv3 - D 3.3 – V1.1 – 2017-08-21 available online at https://www.esa-landcover-cci.org/?q=webfm_send/123 accessed on 2018/08/28
D4	https://www.gdal.org/ accessed on 2018/08/28
D5	https://www.qgis.org/de/site/ accessed on 2018/08/28
D6	https://grass.osgeo.org/ accessed on 2018/08/28
D7	http://step.esa.int/main/toolboxes/snap/ accessed on 2018/08/28
D8	https://climatetoolbox.io/ accessed on 2018/08/28
D9	https://www.giss.nasa.gov/tools/panoply/ accessed on 2018/08/28
D10	https://support.hdfgroup.org/products/java/hdfview/ accessed on 2018/08/28
D11	Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006: World Map of the Köppen-Geiger climate classification updated. Meteorol. Z., 15, 259-263. DOI: 10.1127/0941-2948/2006/0130

Acronyms

Acronym	Definition
ATBD	Algorithm Theoretical Basis Document
Cate	CCI Toolbox
C3S	Copernicus Climate Change Service
CCI	Climate Change Initiative
CDR	Climate Data Record
CDS	Climate Data Store
COPERNICUS	Earth observation programme of European Commission in partnership with the European Space Agency
GDAL	Geospatial Data Abstraction Library
GLC	Global Land Cover 2000 Project
GlobCover2005	Global Land Cover Map for the year 2005
GlobCover2009	Global Land Cover Map for the year 2009
GRASS GIS	Geographic Resources Analysis Support System
EC	European Commission
ECV	Essential Climate Variable
ESA	European Space Agency
FAO	Food and Agriculture Organization
GCS	Geographic Coordinate System
GRIB	GRIdded Binary
HDF	Hierarchical Data Format
Land Cover	Land Cover
LCCS	Land Cover Classification System
NetCDF	Network Common Data Form
Panoply	NetCDF, HDF and GRIB Data Viewer
PFT	Plant Functional Type
PSD	Product Specification Document
PUG	Product User Guide
QGIS	QGIS free and open-source cross-platform desktop geographic information system
SNAP	Sentinel Application Platform
SQAD	System Quality Assurance Document
SSD	System Specification Document
SVR	System Verification Report
UN	United Nations
WGS84	World Geodetic System 84

General definitions

See general definition given in section 1 in D1.

Table of Contents

Scope of the document

This document explains application use cases for the Land Cover (LC) products of the Copernicus Climate Data Store (CDS). It refers to tools that can be used with the data products.

Executive summary

The Copernicus Climate Change Service (C3S) provides Climate Data Records (CDRs) for several Essential Climate Variables (ECVs), among them Land Cover. The first set of LC products made available in CDS is a yearly global map brokered from the ESA CCI Land Cover project. The version 2.0.7cds of the land cover products are brokered from the Land Cover (LC) component of the European Space Agency Climate Change Initiative (ESA CCI) and derived from the ESA CCI Land cover product data set version 2.0.7b.

This tutorial shall help users in working with the ESA CCI Land Cover map data sets after downloading them from CDS. The tutorial briefly describes the ESA CCI Land Cover map data sets. To tackle the variety of requirements the ESA CCI Land Cover project has developed a user tool that allows users to transform the Land Cover products according to their needs. The functionality of the user tool comprises sub-setting, aggregation, and re-projection. Further, cross-walking tables can be applied to map the Land Cover classification system classes to plant functional types (PFTs).

The brokered ESA CCI Land Cover datasets are available as CDR in the CDS.

1 CDR Land Cover Products

As mentioned before, the brokered ESA CCI Land Cover map data sets are delivered as CDR to the C3S. The CDR Land Cover products have been reformatted related to the requirements of the Copernicus Climate Data Store.

1.1 Products description

The product is specified in the PUGs and PSD [D1, D2 and D3].

1.2 Product content

The product content is described in the PUGs [D2 and D3].

1.3 Global and regional CCI-Land Cover legends

Global and regional CCI-Land Cover legends are presented in PUGs [D2 and D3]

1.4 Data access

1.4.1 Climate Data Store

The C3S LC maps are available through the C3S Climate Data Store (CDS). The CDS provides open, free and unrestricted access to a wide range of quality-assured climate datasets. In addition to this, the CDS includes a set of tools for analysing and predicting the impacts of climate change.
The data can be accessed through the CDS using this link: https://cds.climate.copernicus.eu/ and searching for C3S Land Cover. The access to the CDS requires a registration process.

Unfortunately, the applications don't work at the present, as the C3S ICDR Land Cover data is not yet supported by CDS. Therefore, an error message would be given back to the user. Also, the provided example code has to be verified after the release of the data or before in a CDS testing environment, which is the preferred way.

1.4.2 ESA-CCI Land Cover

The data access and the policy are described in the PUGs [D2 and D3].

2 Software Tools

A set of tools to browse and view the content of the Land Cover products are available. The Land Cover map products are delivered in the NetCDF formats. The NetCDF format is supported by commercial software such as ArcGIS, and ENVI. The software can be used simply to visualize the data or to combine Land Cover information with other spatial data (vector or raster layers), to extract temporal series of the yearly products, to compute statistics, etc. The NetCDF format is also supported by several Open Source software such as Panoply, HDFView, Geospatial Data Abstraction Library (GDAL]), QGIS, and the Geographic Resources Analysis Support System (GRASS GIS), and SNAP and CCI Toolbox.

- GDAL [D4] is a library for reading and writing raster geospatial data formats. It is built with a variety of useful command-line utilities for data translation and processing.
- QGIS [D5] is a free and open-source cross-platform desktop geographic information system (GIS) application for viewing, editing, and analysis of geospatial data.
- GRASS GIS [D6]is a free Geographic Information System (GIS) software used for geospatial data management and analysis, image processing, graphics/maps production, spatial modelling, and visualization.
- SNAP [D7] is the ESA Sentinel Toolbox for Earth Observation data processing, analysis and visualisation. It is a modular rich client tool and a command line tool with a generic EO data product abstraction independent of the file format, tiled image memory management, and a graph processing framework for simple and for complex user-defined product transformations and processing.
- CCI Toolbox (Cate) [D8] is a software environment for ingesting, operating on and visualising all ESA Climate Change Initiative data. The access and the processing of the ESA climate data can be managed through a command shell or console terminal. The Cate desktop application provides a graphical user interface with the same functionality provided by the command line interface.
- Panoply [D9] is a data viewer for NetCDF, HDF and GRIB geospatial data.
- HDFView [D10] is a Java-based HDF Viewer, which also supports the NetCDF file format for viewing, and analysis of geospatial data.

3 CCI-Land Cover user tool [D2 and D3][1]

The ESA CCI Land Cover map products are provided at spatial resolution of 300m. All products are in a Plate Carrée projection as global files. However, climate models may need products associated with a coarser spatial resolution, over specific areas (e.g. for regional climate models), and/or in another projection. To tackle the variety of requirements, the CCI-Land Cover project has developed a tool that allows users to adjust the classification layer of the Land Cover products in a way which is suitable to their model. The user tool is available for download from the ESA CCI LC project.
The climate users of the CCI-Land Cover project have established a minimum list of possibilities in terms of spatial resolution and projection that the user tool shall - and does - offer. They are presented in Table 1.

Table 1: Minimum set of projections and spatial resolutions that need to be included in the re-projection, aggregation and subset tool developed by the CCI-Land Cover project

PARAMETER THAT CAN BE ADJUSTED	POSSIBILITIES OFFERED BY THE TOOL
Regional subset ID	Predefined regional subset
	Free specification of regional subset (4 corner coordinates)
Spatial resolution	Original resolution
	0.25 degree
	0.5 degree
	1 degree
	1.875 degree
Projection	Original projection (Plate-Carrée)
	Gaussian grid
Conversion of CCI-Land Cover classes to PFT	ESA CCI Land Cover standard cross walking table
	User defined cross walking table
	Additional classification map

3.1 Re-sampling algorithm for the CCI-Land Cover Map products

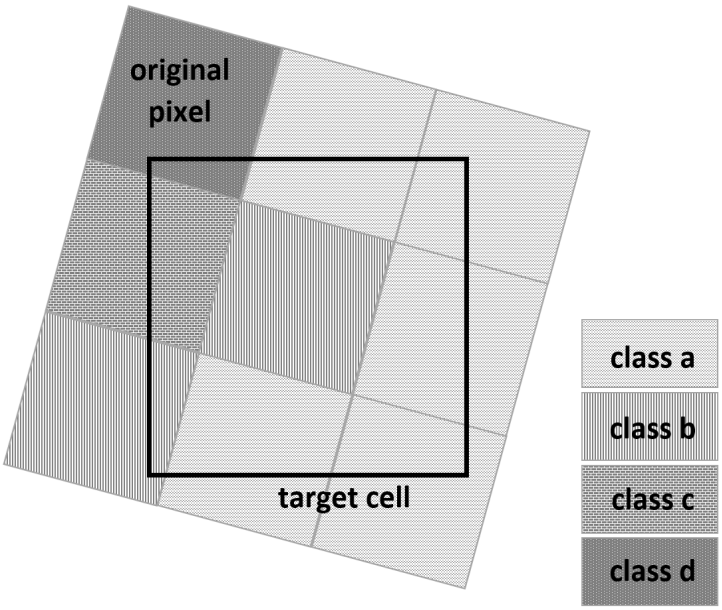
When spatially aggregating land cover class pixels the aggregated land cover map product comprises the following bands:

- the fractional area of each land cover class,
- majority classes
- accuracy
- optionally the fractional area of each PFT.

The majority class n is defined as the CCI-Land Cover class which has the rank n of sorted list of CCI-Land Cover class by fractional area in the target cell (see also Figure 1). The number of majority classes is a parameter which can be defined by user. The rules for the resampling are specified in consultation with the users. So, each original pixel contributes to the target cell according to its overlapping area fraction. Only contributions processed flag set and status “clear land”, “water” or

[1] As mentioned before, the brokered ESA CCI Land Cover map data sets have been reformatted as CDR according to the guidelines of the CDS. The ESA CCI user tool does not yet support the reformatted files.

"snow and ice" are considered. The accuracy is calculated as median of the values of the "algorithmic confidence level" of the contributions.



	Area	Majority class
class a	~ 8/16	1
class b	~ 5/16	2
class c	~ 2/16	3
class d	~ 1/16	4

Figure 1: Aggregating classes - Visualization of the pixel aggregation from the spatial resolution of original Land Cover-CCI Map product into the user defined spatial resolution of the aggregated Land Cover-CCI Map product

3.2 Land Cover LCCS to PFT conversion

Climate modellers often use specific PFT legends in their models. Modellers can use the aggregation tool to apply a conversion from the Land Cover legend to their user-specific PFT legend. The conversion of CCI-Land Cover classes to PFT is based on a cross-walking lookup table. The lookup table that comes with the tool has been approved by the climate modellers of the ESA CCI LC project and is shown in Table 2.

ID	CCI LC map description	Tree				Shrub				Grass		Non-vegetated				
		Broadleaf Evergreen	Broadleaf Deciduous	Needleleaf Evergreen	Needleleaf Deciduous	Broadleaf Evergreen	Broadleaf Deciduous	Needleleaf Evergreen	Needleleaf Deciduous	Natural Grass	Managed Grass	Bare soil	Water	Snow/Ice	No data	Total %
0	No data														100	100
10	Cropland, rainfed										100					100
11	Herbaceous cover										100					100
12	Tree or shrub cover						50				50					100
20	Cropland, irrigated or post-flooding										100					100
30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	5	5			5	5	5		15	60					100
40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	5	5			7.5	10	7.5		25	40					100
50	Tree cover, broadleaved, evergreen, closed to open (>15%)	90				5	5									100
60	Tree cover, broadleaved, deciduous, closed to open (>15%)		70				15			15						100
61	Tree cover, broadleaved, deciduous, closed (>40%)		70				15			15						100
62	Tree cover, broadleaved, deciduous, open (15-40%)		30				25			35		10				100
70	Tree cover, needleleaved, evergreen, closed to open (>15%)			70		5	5	5		15						100
71	Tree cover, needleleaved, evergreen, closed (>40%)			70		5	5	5		15						100
72	Tree cover, needleleaved, evergreen, open (15-40%)			30			5	5		30		30				100
80	Tree cover, needleleaved, deciduous, closed to open (>15%)				70	5	5	5		15						100
81	Tree cover, needleleaved, deciduous, closed (>40%)				70	5	5	5		15						100
82	Tree cover, needleleaved, deciduous, open (15-40%)				30		5	5		30		30				100
90	Tree cover, mixed leaf type (broadleaved and needleleaved)		30	20	10	5	5	5		15		10				100
100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	10	20	5	5	5	10	5		40						100
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	5	10	5		5	10	5		60						100
120	Shrubland					20	20	20		20		20				100
121	Evergreen shrubland					30		30		20		20				100
122	Deciduous shrubland						60			20		20				100
130	Grassland									60		40				100
140	Lichens and mosses									60		40				100
150	Sparse vegetation (tree, shrub, herbaceous cover) (<15%)	1	3	1		1	3	1		5		85				100
152	Sparse shrub (<15%)					2	6	2		5		85				100
153	Sparse herbaceous cover (<15%)									15		85				100
160	Tree cover, flooded, fresh or brakish water	30	30							20			20			100
170	Tree cover, flooded, saline water	60				20							20			100
180	Shrub or herbaceous cover, flooded, fresh/saline/brakish water		5	10			10	5		40			30			100
190	Urban areas		2.5	2.5						15		75	5			100
200	Bare areas											100				100
201	Consolidated bare areas											100				100
202	Unconsolidated bare areas											100				100
210	Water bodies												100			100
220	Permanent snow and ice													100		100

Table 2: Look-up table - conversion of CCI-Land Cover classes to PFT

Users have the option to define and apply their own lookup table instead. Additionally, users can include additional information like a world map of Köppen-Geiger climate classification (v3.10 and see Figure 2, [D11]) and refer to it in the cross-walking table.

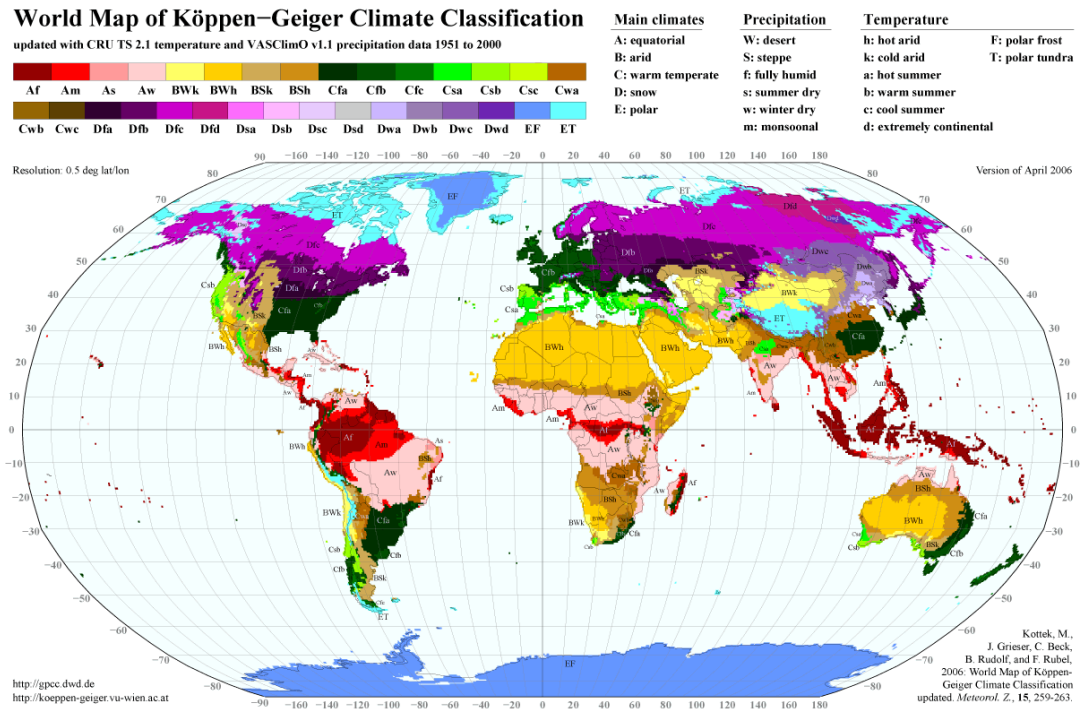


Figure 2: Köppen-Geiger climate classification [D11]

3.3 Examples

Figure 3 shows an example of the global land cover map aggregated at a cell size of 9.8 km and the pixel value represents the majority class 1 w.r.t. the Land Cover class.

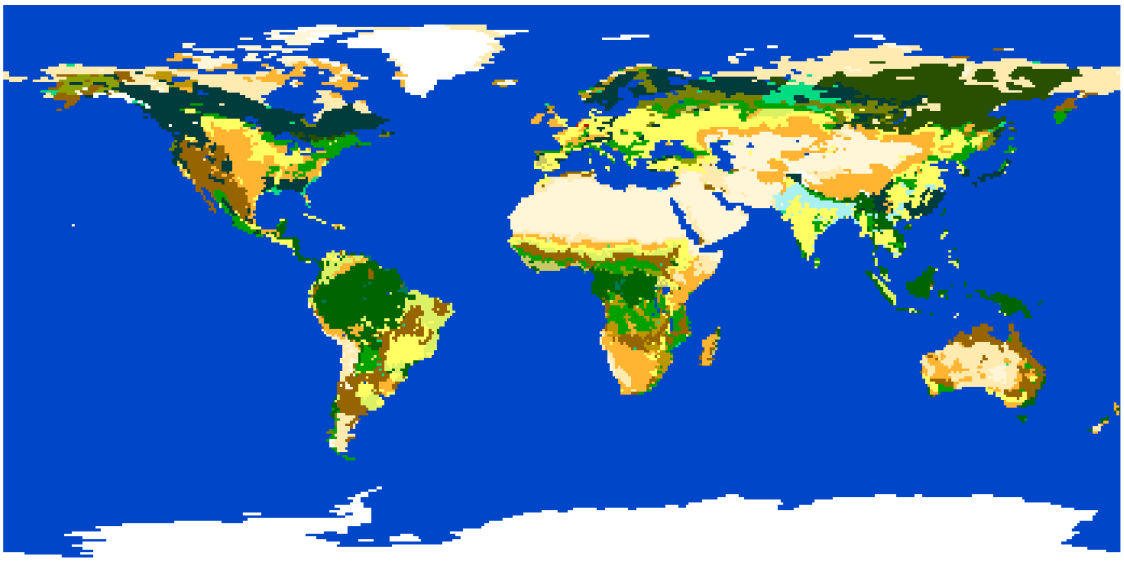


Figure 3: Example of an aggregated global land cover map V1 obtained with the aggregation tool. Its pixel size is 9.8 km, the majority class is 1 and the pixel value represents the Land Cover.

Figure 4 shows an example of the global land cover map aggregated at a cell size of 9.8km and the pixel value represents the area of the Land Cover class 130 - grassland. Figure 5 gives an example of the global land cover map aggregated at a cell size of 9.8km and the pixel value represents the area of the PFT – natural grass.

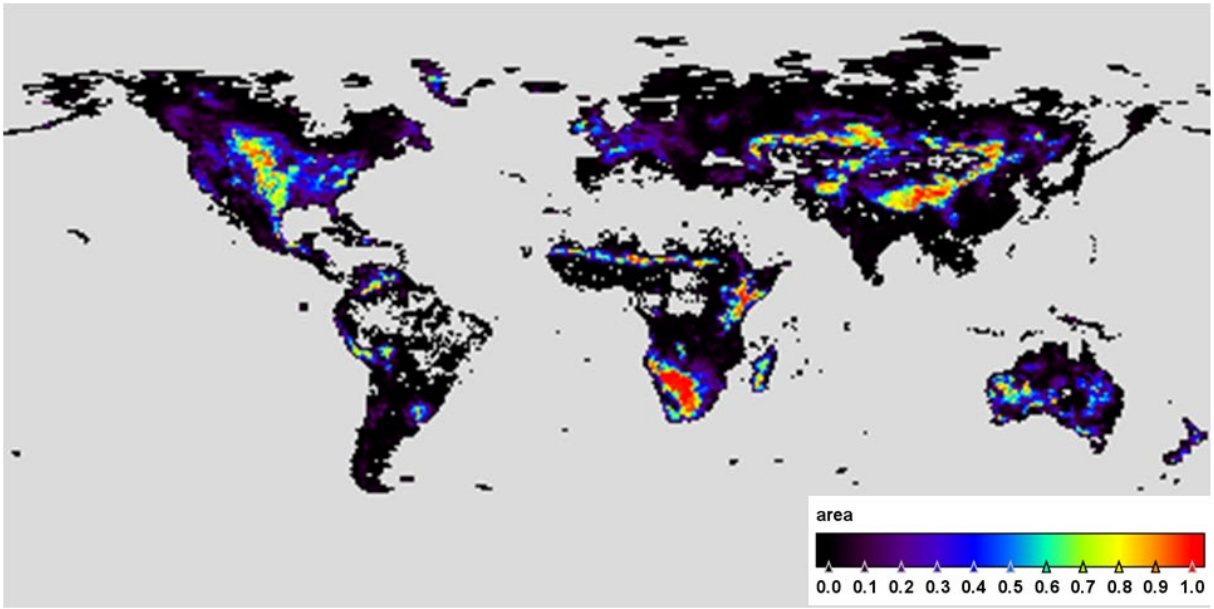


Figure 4: Example of an aggregated CCI Global Land Cover Map V1 obtained with the aggregation tool. Its pixel size is 9.8 km, area of CCI-Land Cover class – 130 – grassland

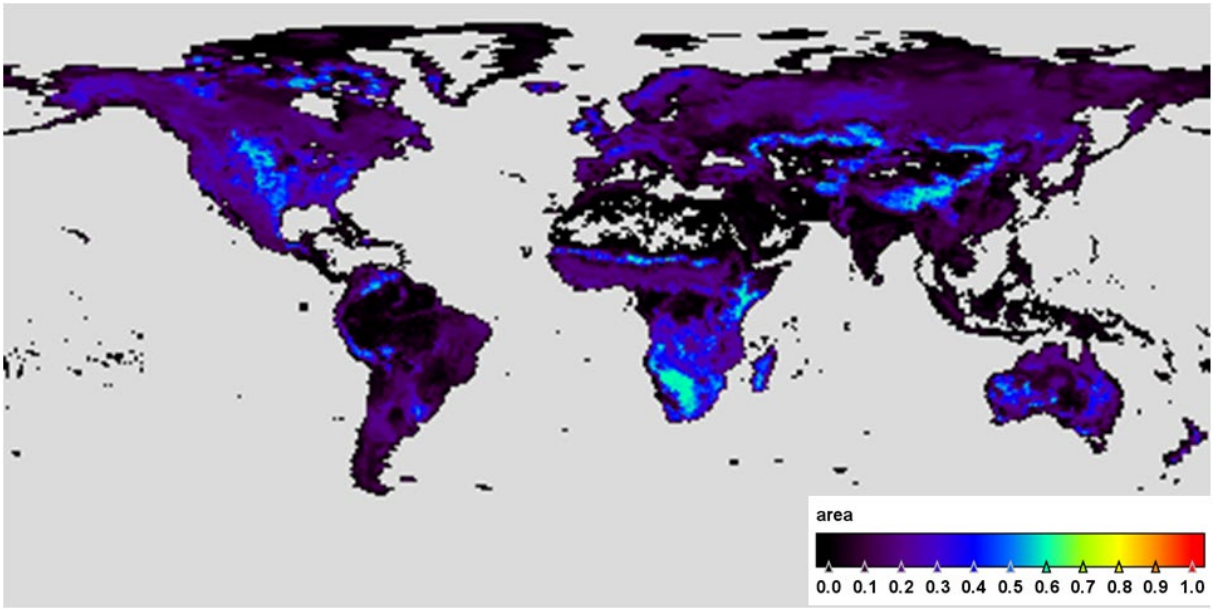


Figure 5: Example of an aggregated CCI Global Land Cover Map V1 obtained with the aggregation tool. Its pixel size is 9.8 km, area of CCI-Land Cover PFT – natural grass

3.4 User tool manual - summary

Further instructions for the user tool can be found in the readme provided together with the tool.

3.4.1 General Note

The CCI-LC User Tool requires the NetCDF-formatted LC files as input, NOT the GeoTIFF-formatted ones. The target files are always written in NetCDF-4 (enhanced model) file format. If the NetCDF-4 Classic file format is needed the standard nccopy tool can be used for conversion. When the REGULAR_GAUSSIAN_GRID is chosen as target grid and a regional subset which crosses the prime meridian is also defined the aggregation or the subsetting process will not work. This affects the predefined regions WESTERN_EUROPE_AND_MEDITERRANEAN and AFRICA.

3.4.2 Installation

As a prerequisite the CCI-LC User Tools require an installed Java SE 64Bit JRE version 7 or higher on the system. It can be obtained from the web page at http://www.oracle.com/technetwork/java/javase/downloads/index.html.

1) Unzip the zip-file in a directory of your choice.
2) Inside the unzipped directory you can find a folder which is named 'bin'. Inside you can find the windows and unix start scripts for the CCI-LC tools.

3.4.3 Execution

All provided scripts are available in windows (*.bat) and unix (*.sh) versions. The scripts need to be invoked from the command line. Navigate to the bin directory of the folder where you have unpacked the tools to. Write the command as described as follows.

3.4.3.1 Aggregation Tool Usage - CCI-LC map products

The following commands have to be applied to aggregate the CCI-LC map products. Furthermore, a description of the parameters is also provided.
The tool splits up the information found in the band "lccs_class" into the Plant Functional Types (PFT) given via look-up table files. The basis for the look-up table is the csv file provided as userPFTConversionTable. If additionally, the additionalUserMapPFTConversionTable csv file is specified, it is used to improve the conversion to PFTs by using the also the additionalUserMap.

```
aggregate-map(.sh/.bat) -PgridName=<name> -PnumRows=<integer>
            -PoutputLCCSClasses=<boolean> -PnumMajorityClasses=<integer>
            -PoutputPFTClasses=<boolean> -PuserPFTConversionTable=<filePath>
            -PadditionalUserMap=<filePath> -PoutputUserMapClasses=<boolean>
            -PadditionalUserMapPFTConversionTable=<filePath>
            -PoutputAccuracy=<boolean>
            -PtargetDir=<dirPath> <sourceFilePath>

Parameter Description:
   For a description of the common aggregation parameters please have a look into the above section
   for the CCI-LC Condition Products. In addition for the aggregation of the CCI-LC Map Products the
   following parameters exist:

   -PoutputLCCSClasses=<boolean>
      Specifies whether the LCCS classes shall be added to the output. This parameter can be
```

omitted. The default is true.
-PnumMajorityClasses=<integer>
Specifies the number of majority classes in the output. This parameter can be omitted, in this case the default (5) is used. A value of 1 will produce an output with just the majority class.
-PoutputPFTClasses=<boolean>
Specifies if a conversion to PFT classes shall be performed and the result added to the output. This parameter can be omitted. The default is true.
-PuserPFTConversionTable=<filePath>
Specifies the path to a user defined PFT conversion table. If not given the default CCI-LC conversion table will be used. For a description of the file format see further down.
-PadditionalUserMap=<filePath>
A map containing additional classes which can be used to refine the conversion from LCCS to PFT classes.
-PoutputUserMapClasses=<boolean>
Whether or not to add the classes of the user map to the output.
This option is only applicable if the additional user map is given too.
-PadditionalUserMapPFTConversionTable=<filePath>
The conversion table from LCCS to PFTs considering the additional user map.
This option is only applicable if the additional user map is given too.
-PoutputAccuracy=<boolean>
Specifies the computation of the accuracy shall be performed and the result added to the output. This parameter can be omitted. The default is true.
<sourceFilePath>
Is the path to the source NetCDF-4 file.

The PFT conversion table, also known as Cross Walking Table, describes the conversion of the LCCS classes to PFTs. The file can start with an optional comment. If the comment is used the first line must start with '#' in order to indicate the comment. Multiple lines are not supported. The comment ('pft_table_comment') is included as an attribute into the NetCDF output file. The actual PFT table starts with a table header. Each column of the header defines one PFT except the first. The first column is for the LCCS class indices. The subsequent data rows, one for each LCCS class, define the conversion from corresponding class to the PFTs. Each cell specifies the percentage of the PFT, floating point values can be used. Zero percentage can be omitted. Columns are separated with the pipe ('|') symbol and the column header names are used as band names.

PFT conversion table example:

```
# An optional comment describing the conversion table
LCCS Class|Tree Broadleaf Evergreen|...|Managed Grass|Bare soil|Water|Snow/Ice|No data
0||...|||||100
10||...|100||||
11||...|100||||
12||...|50||||
20||...|100||||
30|5|...|60||||
40|5|...|25|40|||
...
220||...||||100|
```

The additionalUserMapPFTConversionTable has a similar structure like the PFT conversion table. The first column is again the LCCS class, the second the class in the additional user map. If one LCCS

class, user class combination is missing the algorithm falls back to the userPFTConversionTable, if given or to the defaults of the CCI-LC conversion table

Additional conversion table example:

```
# Koeppen-Geiger Map
LCCS_Class|Köppen_Geiger_Class|PFT_1|PFT_2|_PFT3|...|No_data
10|11|||||||||14|86|||
10|12|||||||||11|89|||
10|13|||||||||10|90|||
10|14|||||||||4|96|||
10|21|||||||||6|94|||
10|22|||||||||20|80|||
10|26|||||||||13|87|||
20|11|||||||||15|85|||
20|12|||||||||21|79|||
20|26|||||||||2|98|||
```

3.4.3.2 Subset Tool Usage

In order to create a regional subset of a map, condition or aggregated product the subset tool can be used. As parameter either one of the predefined regions can be selected or the bounds of the desired region can be specified. The target file is written into the directory of the source file. The following commands have to be applied to create subsets the CCI-LC map products. Furthermore, a description of the parameters is also provided.

```
subset(.sh/.bat) -PpredefinedRegion=<regionName> -PtargetDir=<dirPath> <sourceFilePath>
      or
subset(.sh/.bat) -Pnorth=<degree> -Peast=<degree> -Psouth=<degree> -Pwest=<degree> -PtargetDir=<dirPath>
                    <sourceFilePath>

-PpredefinedRegion=<regionName>
   Specifies one of the available predefined regions.
   Valid Values are: NORTH_AMERICA, CENTRAL_AMERICA, WESTERN_EUROPE_AND_MEDITERRANEAN,
              ASIA, AFRICA, SOUTH_EAST_ASIA, AUSTRALIA_AND_NEW_ZEALAND, GREENLAND, SOUTH_AMERICA
-Pnorth=<degree>
   Specifies north bound of the regional subset.
-Peast=<degree>
   Specifies east bound of the regional subset. If the grid of the source product is REGULAR_GAUSSIAN_GRID
   coordinates the values must be between 0 and 360.
-Psouth=<degree>
   Specifies south bound of the regional subset.
-Pwest=<degree>
   Specifies west bound of the regional subset. If the grid of the source product is REGULAR_GAUSSIAN_GRID
   coordinates the values must be between 0 and 360.
-PtargetDir=<dirPath>
   Specifies the directory where the target will be written. It is written as NetCDF-4 file.
   If already a file with the same name/path exists, it will be overwritten.
   (see "Output File Naming Convention" )
<sourceFilePath>
   The source file to create a regional subset from.
```

3.4.4 Output File Naming Convention

The following sections explain the relation between the input and output product file naming.

Split Points:
Map Product: ESACCI-LC-L4-LCCS-Map-{sRes}m-P{tRes}Y-{epoch}-v{versNr}.nc
^
|--- Split Position
Examples Map Result:
Aggregation:
Input : ESACCI-LC-L4-LCCS-Map-300m-P5Y-2006-v2.nc

Output : ESACCI-LC-L4-LCCS-Map-300m-P5Y-aggregated-0.083333Deg-2006-v2.nc

Subset:
Input : ESACCI-LC-L4-LCCS-Map-300m-P5Y-aggregated-0.083333Deg-2006-v2.nc

Output : ESACCI-LC-L4-LCCS-Map-300m-P5Y-aggregated-0.083333Deg-EUROPE-2006-v2.nc
Output : ESACCI-LC-L4-LCCS-Map-300m-P5Y-aggregated-0.083333Deg-ASIA-2006-v2.nc
Output : ESACCI-LC-L4-LCCS-Map-300m-P5Y-aggregated-0.083333Deg-USER_REGION-2006-v2.nc

Copernicus Climate Change Service

ECMWF - Shinfield Park, Reading RG2 9AX, UK

Contact: info@copernicus-climate.eu

climate.copernicus.eu copernicus.eu ecmwf.int