



WorldCover

Product User Manual

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Acronyms and Abbreviations

AWS	Amazon Web Services
CCI	Climate Change Initiative
CEOS	Committee on Earth Observation Satellites
COG	Cloud Optimized GeoTIFF
CGLS	Copernicus Global Land Service
CRS	Coordinate Reference System
DEM	Digital Elevation Model
EO	Earth Observation
ESA	European Space Agency
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographic Information System
GLC	Global Land Cover
GRD	Ground Range Detected
LC	Land Cover
LCCS	Land Cover Classification System
UN	United Nations
PSU	Primary Sampling Unit
PUM	Product User Manual
SAR	Synthetic Aperture Radar
SCL	Scene Classification Layer
SSU	Secondary Sampling Unit
UTM	Universal Transverse Mercator
VI	Vegetation Indices

1 Introduction

1.1 Project objectives and approach

In an ever-changing environment, the need for accurate, timely and high-resolution information on land use/land cover and its changes has increased tremendously. However, until now, regional or continental land cover maps either used low-resolution images (>100 m) as input or were based exclusively on high-resolution optical Earth observation data, such as Sentinel-2 or Landsat. The use of Synthetic Aperture Radar (SAR) data such as Sentinel-1 to produce large area land cover maps is still in its infancy.

For this purpose and inspired by the [2017 WorldCover conference](#) (attended by more than 400 participants) the European Space Agency (ESA) initiated the WorldCover project. The key outcome of this project was the release in October 2021 of a freely accessible global land cover product at 10 m resolution for 2020 based on both Sentinel-1 and Sentinel-2 data, containing 11 land cover classes and independently validated with a global overall accuracy of 74.4%.

Following the positive feedback from the users, ESA decided to extend the WorldCover project and requested the WorldCover consortium to also produce a 2021 version of the product with even higher quality. This new WorldCover map for 2021 was released on 28 October 2022 and resulted in a global overall accuracy of 76.7%.

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.

1.2 Purpose of the document

This Product User Manual (PUM) describes the WorldCover Land Cover products and contains the required information to use the products.

The PUM is the primary document that users should read before handling the product. It gives an overview of the product characteristics, in terms of algorithm and technical characteristics and describes the known limitations and a summary of the independent validation results.

1.3 Overview

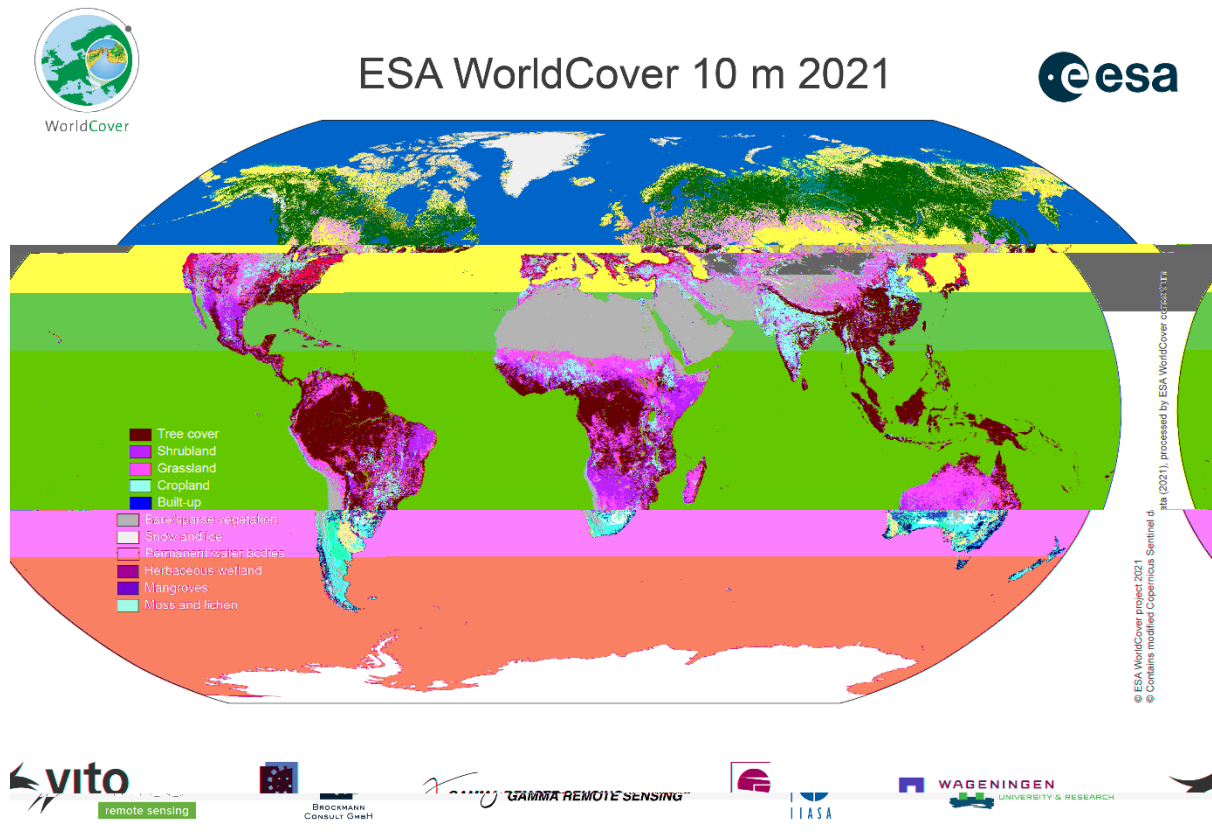


Figure 1: The WorldCover 2021 Map v200

In the following sections first the retrieval methodology of the WorldCover product is summarized (section 2) followed by a description of the technical properties of the product (section 3). Next, we list some identified known limitations of the product (section 4) as well as more information on how to access the product (section 5). Finally, also a summary of the independent validation results is provided (section 6).

2 Algorithm

The ESA WorldCover global land cover products build further on the GlobCover and CCI Land Cover experiences from the European Space Agency (Arino et al. 2008; ESA 2017). The algorithm used to generate the ESA WorldCover products is based on the algorithm to produce the dynamic yearly Copernicus Global Land Service Land Cover (CGLS-LC) map at 100 m resolution (Buchhorn et al., 2020a).

2.1 Summary

Below more details are provided for v200 of the WorldCover retrieval algorithm. For more details on v100 of the algorithm version used in the 2020 map, the reader is referred to V1.0 of the Product User Manual available at esa-worldcover.org/en/data-access.

The methodology for producing the WorldCover land cover products can be split in 3 separate workflows (Figure 2): **Data pre-processing**, ii) **Classification** and iii) **Map generation**. The classification workflow is further subdivided in a training & prediction phase.

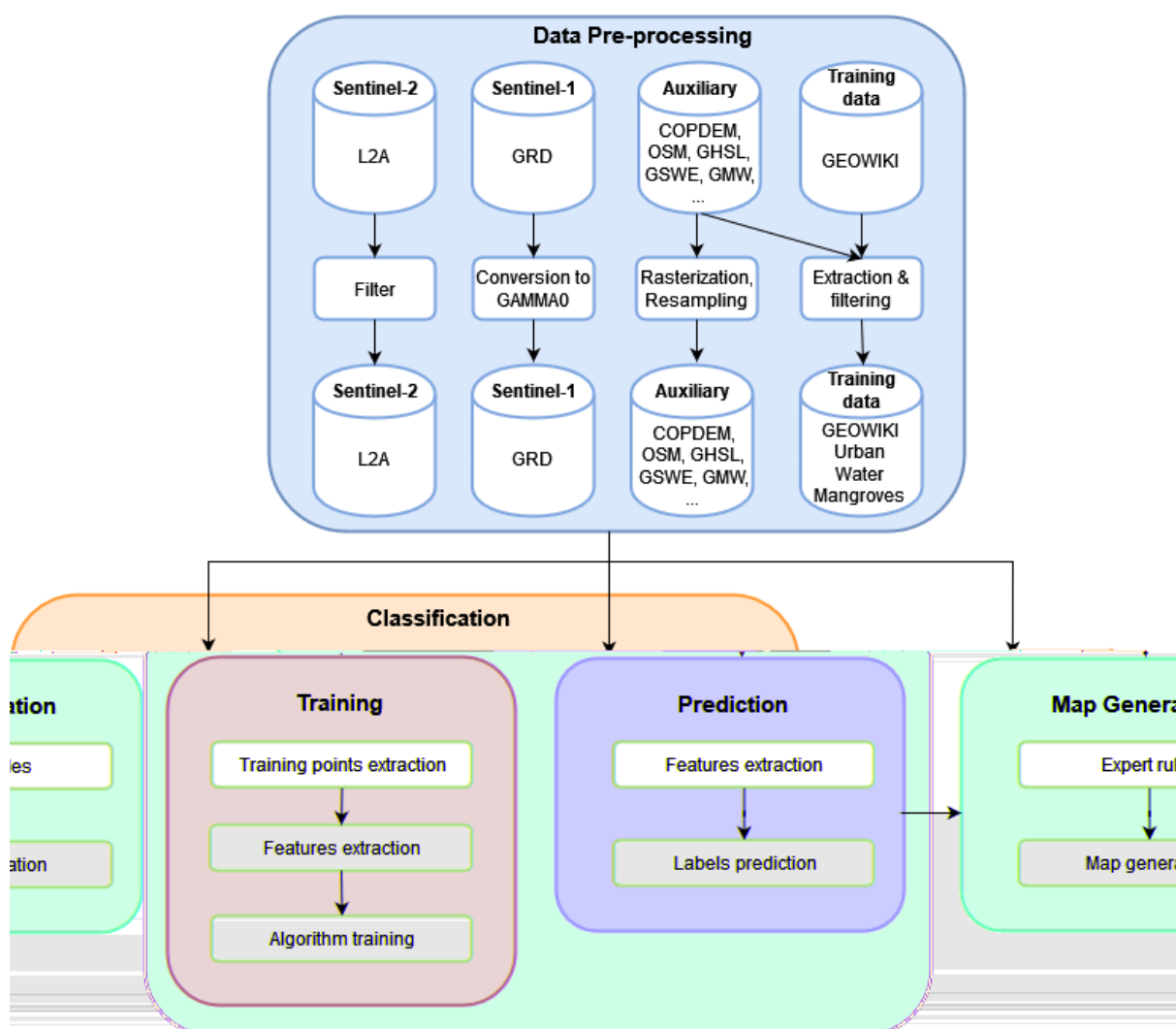


Figure 2: Combined workflow to generate the WorldCover land cover product

As a first step in the processing, Level 2A (L2A) and Ground Range Detected (GRD) products for Sentinel-2 (S2) and Sentinel-1 (S1) respectively, are selected and either filtered for cloud cover (Sentinel-2) or terrain corrected to Gamma0 backscatter time series (for Sentinel-1) which are

geocoded to the Sentinel-2 grid. To reduce data redundancy, a maximum of one observation per day per tile is processed. In case of multiple observations per day, the first observation with the highest number of valid data pixels is kept.

Next, clouds, cloud shadows, cirrus and saturated pixels are removed in the Sentinel-2 reflectance bands using the scene classification layer (SCL) of the L2A product. Ten days median composites (using a 20 days moving window) are computed from the band time series, eliminating further noise, or pixels not correctly masked by the SCL layer. The remaining missing values are then filled by estimating their value from a linear interpolation between the closest available values in the time series. After the time series are pre-processed, additional vegetation indices (VI) for each time series step are calculated.

Starting from those cleaned Sentinel-2 surface reflectance and VI time series, descriptive statistics are computed for each band and VI. These includes the 10th, 50th, 90th percentiles and the interquartile range (75th percentile – 25th percentile). The same features are calculated on the S1 VV and VH backscatter time series as well. For S1 bands, an additional multitemporal speckle filter is used before compositing the timeseries. Altitude and slope are extracted from the Copernicus Global 30 m Digital Elevation Model (DEM) (Fahrland et al., 2019) and used as features as well. A series of spatial localizing features are also included: the position of each pixel (latitude & longitude) and the biome and realm features derived from the Ecoregions2017 layer (Dinerstein et al., 2017). Yearly meteorological features are also derived from the TerraClimate dataset (Abatzoglou et al., 2018). The yearly mean and standard deviation is computed for 7 variables from the dataset (reference evapotranspiration, snow water equivalent, minimum temperature, maximum temperature, vapor pressure, vapor pressure deficit and wind speed). Overall, 64 features are extracted from Sentinel-2, 12 features from Sentinel-1, 2 features from the DEMs, 23 positional features and 14 meteorological features, for a total of 115 features.

In the training phase, these features are extracted for each training location, from which training points are randomly sampled. For each class, 10% of the points are sampled, with a maximum of 30 points per class per location. The training points selected are randomly splitted in training and test sets and used for training different models (scenarios) with a gradient boosting decision tree algorithm (CatBoost) (Prokhorenkova et al., 2018). Three models are trained in total, one using all the extracted features (combined model), one excluding S1 features (L2A model), and one excluding S2 features (GAMMA0 model). In the classification phase, the same steps are carried out until the features are extracted, at that point the models/scenarios trained during the training phase are loaded and used to predict the labels of the input data together with the class probabilities.

Finally, the different scenarios are combined into a final land cover map through the application of different expert rules and subsequently tiled into 3 x 3 degree tiles in geographic projection (EPSG:4326). Some of these expert rules use the following auxiliary datasets (OpenStreetMap (OpenStreetMap Contributors, 2021), Global Mangrove Watch (Bunting et al., 2022), Global Human Settlement Layer (Corbane et al., 2020a, 2020b), World Settlement Footprint 2019 (Marconcini et al., 2021) and ESA WorldCover 2020 (Zanaga et al., 2021). It is important to note that these auxiliary datasets are not imprinted in the final land cover map but only support the decision of the final class attribution. These expert rules address two main limitations of the current methodology: artefacts deriving from artefacts or low-quality input signal (100% cloud cover/ice/snow areas) and spectral mixing leading to confusion between bare areas and urban and between mangroves and trees.

2.2 Differences to the previous version

Since the **WorldCover maps for 2020 and 2021 were generated with different algorithm versions** (v100 and v200, respectively), changes between the maps should be treated with caution, as they include both changes in real land cover and changes due to the used algorithms (see Figure 3 and Figure 4). In fact, most changes between both maps are due to changes in the used algorithms.

Compared to v100, v200 mainly uses an improved training dataset and features leading to an overall improved retrieval of the different land cover classes (Table 1). Additionally, v200 uses slightly optimized settings for training the algorithm as well as an optimized set of expert rules. The product description (see section 3; i.e. file naming, file format, product content & product characteristics) is however identical for both versions.

Table 1: Successive versions of the WorldCover products.

Algorithm Version	Main characteristics
v100	Used to generate the WorldCover 2020 product . A total of 259734 training locations was used and 131 features.
v200	Used to generate the WorldCover 2021 product . A total of 319415 training locations was used and 115 features

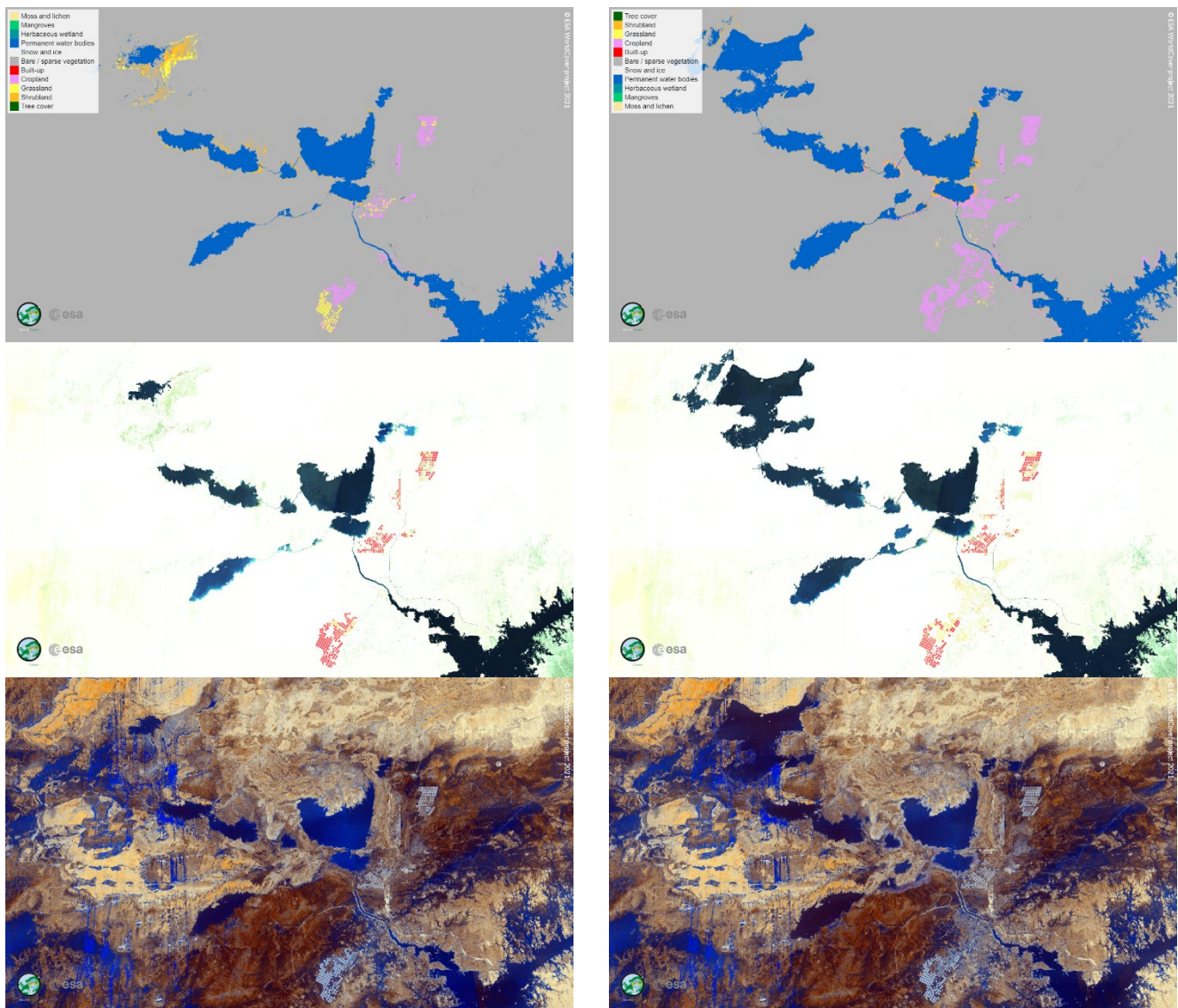


Figure 3: WorldCover 2020 map (topleft), WorldCover 2021 map (topright), Sentinel-2 median false colour composite for 2020 (middle left), Sentinel-2 median false colour composite for 2021 (middle right), Sentinel-1 median false colour composite for 2020 (bottom left) and Sentinel-1 median false colour composite for 2021 (bottom right) over an area in Egypt (31.35°E, 23.00°W) showing a difference in the permanent water bodies and cropland classes (i.e. actual land cover changes) between 2020 and 2021 as well as a better mapping of cropland (i.e. algorithm change) in 2021 (less cropland omission) compared to 2020

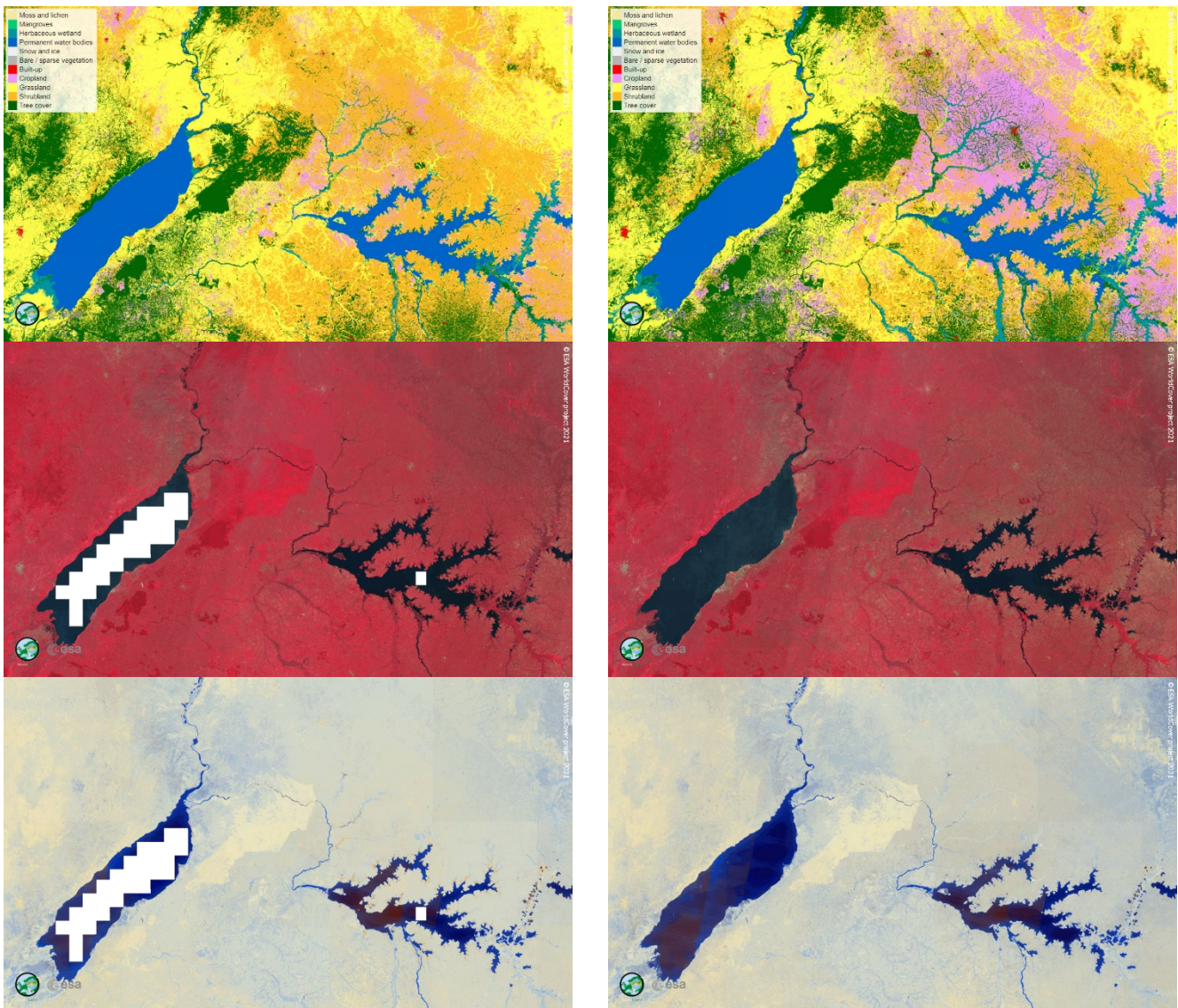


Figure 4: WorldCover 2020 map (topleft), WorldCover 2021 map (topright), Sentinel-2 median false colour composite for 2020 (middle left), Sentinel-2 median false colour composite for 2021 (middle right), Sentinel-1 median false colour composite for 2020 (bottom left) and Sentinel-1 median false colour composite for 2021 (bottom right) over an area in Uganda (31.35°E, 23.00°W) mainly showing changes due to the improved retrieval algorithm in v200 leading to a better cropland and wetland mapping in the WorldCover 2021 map compared to WorldCover 2020.

3 Product description

The ESA WorldCover products are provided per 3 x 3 degree tile (Figure 5), 2651 in total. Each tile contains a set of 2 Cloud Optimized GeoTIFF (COG) files corresponding to the following data layers:

- **Map:** Land cover map with 11 classes
- **InputQuality:** Three band GeoTIFF providing three per pixel quality indicators of the Sentinel-1 and Sentinel-2 input data

Tiles are provided in EPSG:4326, geographic latitude/longitude CRS.

3.1 File naming

The GeoTIFF files follow this naming convention:

ESA_WorldCover_10m_<YEAR>_<VERSION>_<TILE>_<LAYER>.tif e.g.
ESA_WorldCover_10m_2021_v200_S48E036_Map.tif

where

- “ESA_WorldCover_10m” indicates this is the 10 m resolution ESA WorldCover product
- <YEAR> indicates the reference year (observation period) in four digits (e.g. 2021)
- <VERSION> shows the product version. The version denoted as vMmr (e.g. v200), with ‘M’ representing the major version (e.g. v2), ‘m’ the minor version (starting from 0) and ‘r’ the production run number (starting from 0)
- <TILE> the designation of the 3 x 3 degree tile, composed of the 2-digit latitude and 3-digit longitude of the lower-left corner (Figure 5)
Example: S48E036 for the tile covering the area from 36E to 39E and 48S to 45S.
- <LAYER> gives the name of the data layer (see Table 2; e.g. Map)

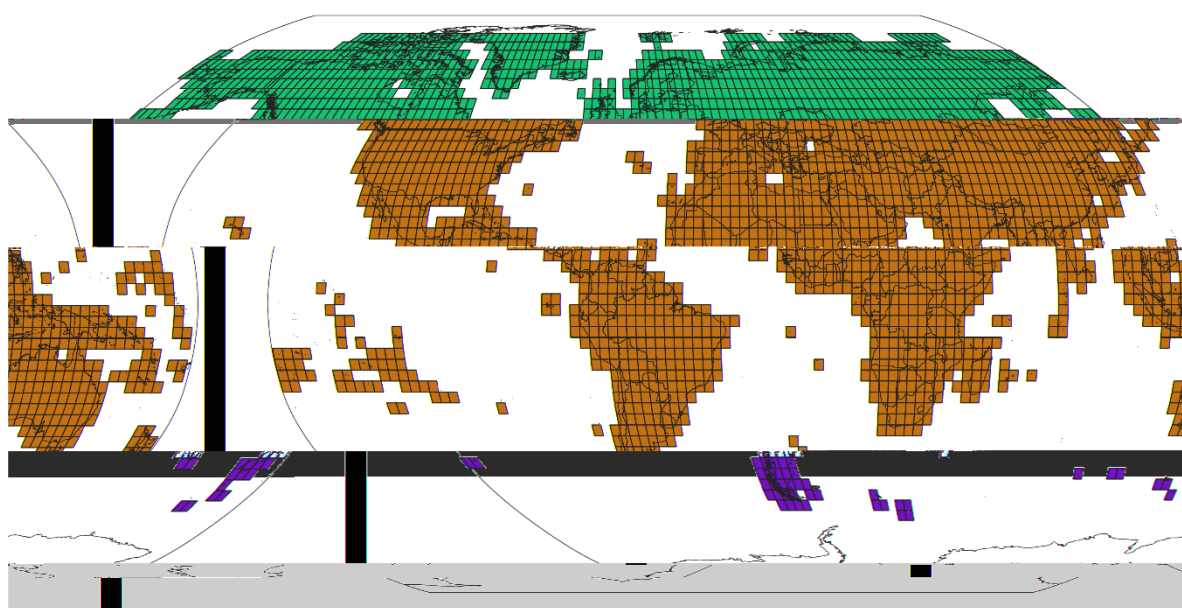


Figure 5: Scheme of the 3 x 3 degree tiles

Table 2: Land Cover layer names in the filename

Layer in filename	Description
Map	Main discrete classification according to FAO LCCS scheme, see Table 3
InputQuality	Per pixel quality indicator showing the quality of the EO input data 3 band GeoTIFF, see 3.3.2

3.2 File format

The data layers of the WorldCover product are provided as **Cloud Optimized GeoTIFF (COG)** files that are internally compressed (DEFLATE), have an internal tiling of size 1024, include overviews on levels 2, 4, 8, 16, 32 and 64 for faster loading in Geographic Information System (GIS) and include standard metadata attributes.

All land cover layers are stored as **single bytes (Map) or UINT16 (InputQuality)** per pixel, without scaling or offset.

3.3 Product content

3.3.1 Map: Land cover classification

The discrete classification **map** provides **11 classes** and is defined using the Land Cover Classification System (LCCS) developed by the United Nations (UN) Food and Agriculture Organization (FAO). The UN-LCCS system was designed as a hierarchical classification, which allows adjusting the thematic detail of the legend to the amount of information available

Table 3: Coding of the Map layer and definition of the classes

Map code	Land Cover Class	LCCS code	Definition	Color code (RGB)
10	Tree cover	A12A3 // A11A1 A24A3C1(C2)- R1(R2)	This class includes any geographic area dominated by trees with a cover of 10% or more. Other land cover classes (shrubs and/or herbs in the understorey, built-up, permanent water bodies, ...) can be present below the canopy, even with a density higher than trees. Areas planted with trees for afforestation purposes and plantations (e.g. oil palm, olive trees) are included in this class. This class also includes tree covered areas seasonally or permanently flooded with fresh water except for mangroves.	0,100,0
20	Shrubland	A12A4 // A11A2	This class includes any geographic area dominated by natural shrubs having a cover of 10% or more. Shrubs are defined as woody perennial plants with persistent and woody stems and without any defined main stem being less than 5 m tall. Trees can be present in scattered form if their cover is less than 10%. Herbaceous plants can also be present at any density. The shrub foliage can be either evergreen or deciduous.	255, 187, 34
30	Grassland	A12A2	This class includes any geographic area dominated by natural herbaceous plants (Plants without persistent stem or shoots above ground and lacking definite firm structure): (grasslands, prairies, steppes, savannahs, pastures) with a cover of 10% or more, irrespective of different human and/or animal activities, such as: grazing, selective fire management etc. Woody plants (trees and/or shrubs) can be present assuming their cover is less than 10%. It may also contain uncultivated cropland areas (without harvest/ bare soil period) in the reference year	255, 255, 76
40	Cropland	A11A3(A4)(A5) // A23	Land covered with annual cropland that is sowed/planted and harvestable at least once within the 12 months after the sowing/planting date. The annual cropland produces an herbaceous cover and is sometimes combined with some tree or woody vegetation. Note that perennial woody crops will be classified as the appropriate tree cover or shrub land cover type. Greenhouses are considered as built-up.	240, 150, 255
50	Built-up	B15A1	Land covered by buildings, roads and other man-made structures such as railroads. Buildings include both residential and industrial building. Urban green (parks, sport facilities) is not included in this class. Waste dump deposits and extraction sites are considered as bare.	250, 0, 0
60	Bare / sparse vegetation	B16A1(A2) // B15A2	Lands with exposed soil, sand, or rocks and never has more than 10 % vegetated cover during any time of the year	180, 180, 180
70	Snow and Ice	B28A2(A3)	This class includes any geographic area covered by snow or glaciers persistently	240, 240, 240
80	Permanent water bodies	B28A1(B1) // B27A1(B1)	This class includes any geographic area covered for most of the year (more than 9 months) by water bodies: lakes, reservoirs, and rivers. Can be either fresh or salt-water bodies. In some cases the water can be frozen for part of the year (less than 9 months).	0, 100, 200
90	Herbaceous wetland	A24A2	Land dominated by natural herbaceous vegetation (cover of 10% or more) that is permanently or regularly flooded by fresh, brackish or salt water. It excludes unvegetated sediment (see 60), swamp forests (classified as tree cover) and mangroves see 95)	0, 150, 160
95	Mangroves	A24A3C5-R3	Taxonomically diverse, salt-tolerant tree and other plant species which thrive in intertidal zones of sheltered tropical shores, "overwash" islands, and estuaries.	0, 207, 117
100	Moss and lichen	A12A7	Land covered with lichens and/or mosses. Lichens are composite organisms formed from the symbiotic association of fungi and algae. Mosses contain photo-autotrophic land plants without true leaves, stems, roots but with leaf-and stemlike organs.	250, 230, 160

3.3.2 InputQuality: Quality layer

Per pixel quality indicator showing the quality of the Earth Observation (EO) input data. The layer is a 3 band GeoTIFF with

- Band 1: Number of Sentinel-1 GAMMA0 observations used in the classification workflow
- Band 2: Number of Sentinel-2 L2A observations used in the classification workflow
- Band 3 Percentage (0-100) of invalid S2 observations discarded in the classification workflow (after cloud and cloud shadow filtering).

Combining Band 2 and Band 3 yields the total absolute number of valid Sentinel-2 L2A observations used in the classification workflow.

3.4 Product characteristics

3.4.1 Projection and grid Information

The WorldCover products are delivered in a regular latitude/longitude grid (EPSG:4326) (Figure 5) with the ellipsoid WGS 1984 (Terrestrial radius=6378 km). The resolution of the grid is 1°/12000 or approximately 10 m at equator for the Map product. The InputQuality layer is provided at 1/2000 or approximately 60 m at equator

3.4.2 Spatial Information

The WorldCover product is constrained to all land areas observed by Sentinel-2 in either 2020 or 2021 except for areas in Antarctica (see Figure 5). In the north, the WorldCover product is limited to 82.75°N.

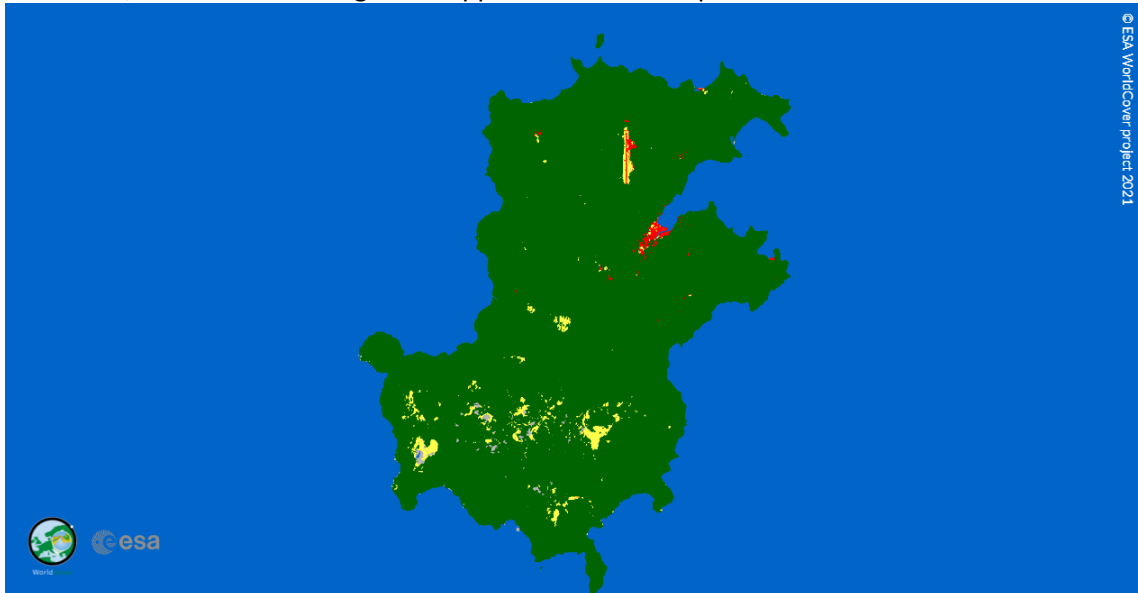
3.4.3 Temporal information

The products represent the **land cover for 2020 (WorldCover 2020 v100) or 2021 (WorldCover 2020 v200)**, from 01 January to 31 December. Sentinel-1 and Sentinel-2 data covering the reference year is used in its processing.

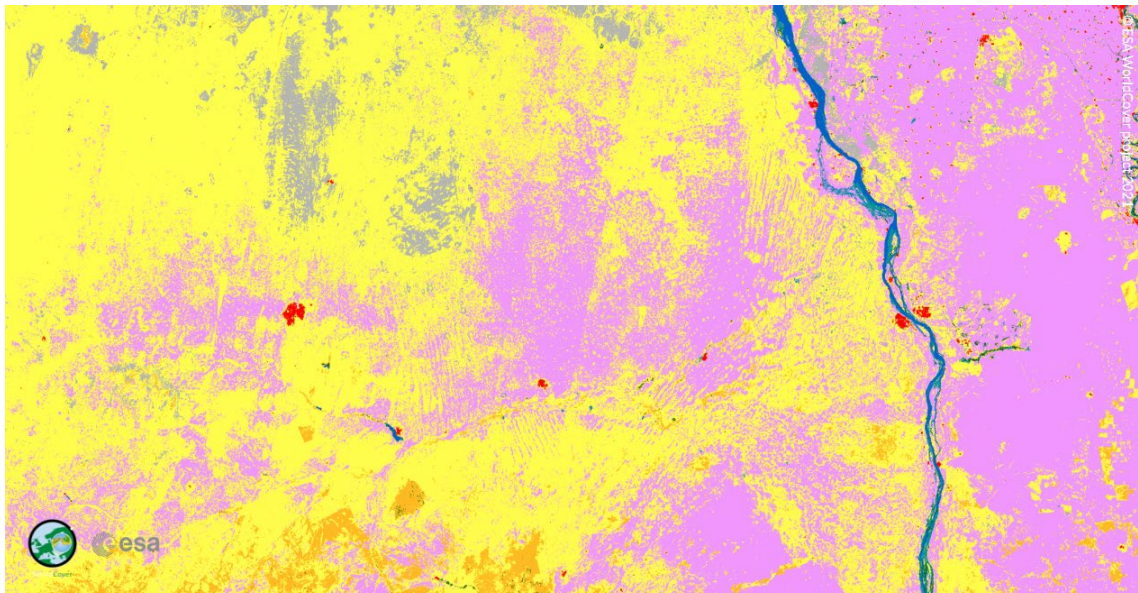
4 Known limitations

Below we identify a non-exhaustive list of limitations in the WorldCover v200 (2021) products. For more details on the limitations in WorldCover v100 (2020), the reader is referred to V1.0 of the Product User Manual available at esa-worldcover.org/en/data-access.

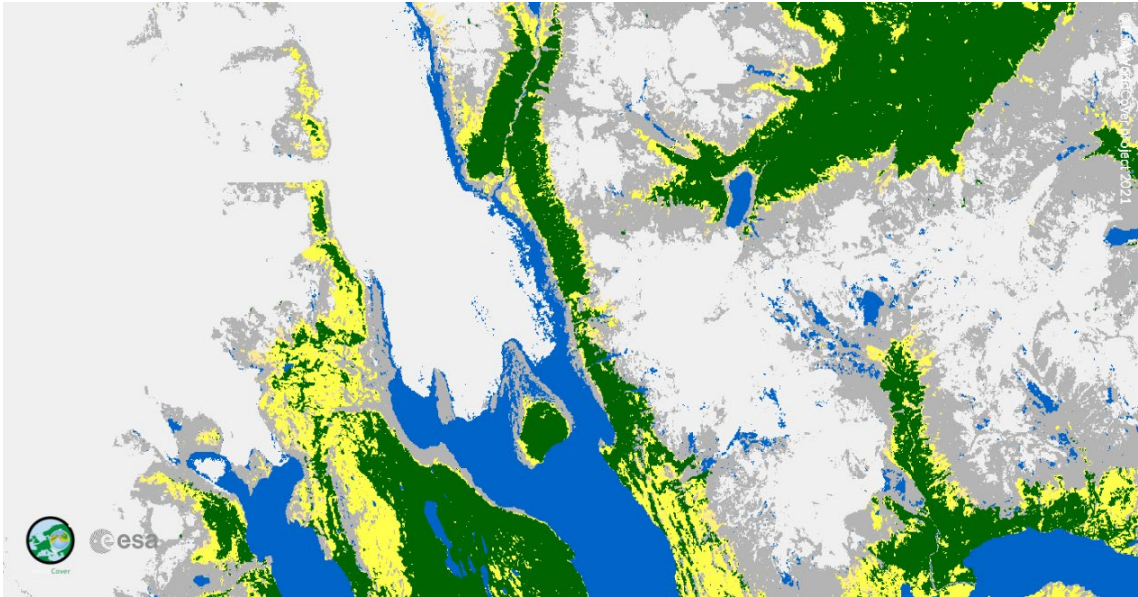
- Cloud artefacts in areas with a high cloud cover % (see e.g. 7.38°E; 1.58°N): Despite the use of Sentinel-1, cloud artefacts might still appear in areas with persistent cloud cover.



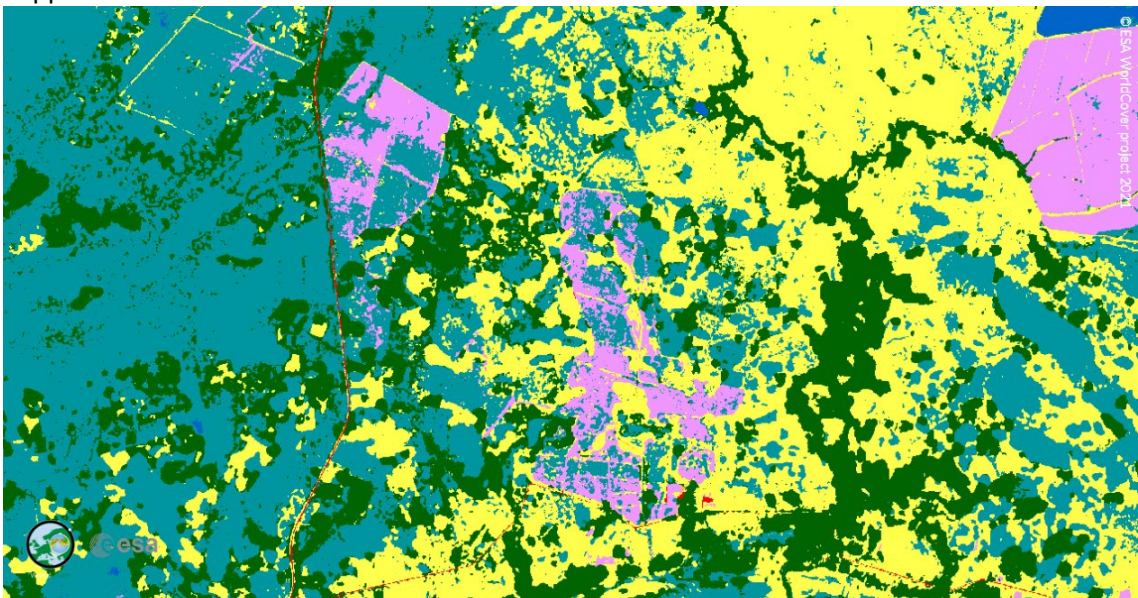
- Hard borders (see e.g. 31.40°E, 13.20°N): In areas with a high confusion between land cover classes, Sentinel-2 orbit borders or block borders might be visible due to sensitivity of the model inference to the different amount of observations/input signal between neighbouring areas.



- Water on glaciers/ice sheets/mountain shadows (e.g. 73.28°W, 49.89°S): Some areas in the ablation zone of glaciers & mountain shadows are sometimes misclassified as water bodies.



- Agriculture vs wetland confusion (e.g. 56.73°W, 27.28°S): Due to the high spectral similarity between (irrigated) agriculture and herbaceous wetland, sometimes misclassifications happen between those classes



In order to improve the map, users are encouraged to give feedback on artefacts/misclassifications via a dedicated feedback tool embedded in WorldCover viewer (see 5.3.2)

5 Data Access and citation

5.1 License

The WorldCover product is provided free of charge, without restriction of use. For the full license information see the [Creative Commons Attribution 4.0 International License](#)

Publications, models and data products that make use of these datasets must include proper acknowledgement, including citing the datasets and the journal article as in the following citation.

5.2 Citation

A reference publication on the product is in preparation

If you are using the data as a layer in a published map, please include the following attribution text: '© ESA WorldCover project [year] / Contains modified Copernicus Sentinel data ([year]) processed by ESA WorldCover consortium'

With year either 2020 or 2021 for the WorldCover 2020 and 2021 map, respectively

To cite these maps as data source in your publication, please add:

- WorldCover 2020
Zanaga, D., Van De Kerchove, R., De Keersmaecker, W., Souverijns, N., Brockmann, C., Quast, R., Wevers, J., Grosu, A., Paccini, A., Vergnaud, S., Cartus, O., Santoro, M., Fritz, S., Georgieva, I., Lesiv, M., Carter, S., Herold, M., Li, Linlin, Tsendbazar, N.E., Ramoino, F., Arino, O., 2021. ESA WorldCover 10 m 2020 v100. [doi:10.5281/zenodo.5571936](https://doi.org/10.5281/zenodo.5571936).
- WorldCover 2021
Zanaga, D., Van De Kerchove, R., Daems, D., De Keersmaecker, W., Brockmann, C., Kirches, G., Wevers, J., Cartus, O., Santoro, M., Fritz, S., Lesiv, M., Herold, M., Tsendbazar, N.E., Xu, P., Ramoino, F., Arino, O., 2022. ESA WorldCover 10 m 2021 v200. [doi:10.5281/zenodo.7254221](https://doi.org/10.5281/zenodo.7254221).

5.3 Delivery Mechanisms

The ESA WorldCover products are delivered in **3x3 degree tiles** as **Cloud Optimized GeoTIFFs (COGs)** in **EPSG:4326 projection** (geographic latitude/longitude CRS). There are **2651 tiles**

Each tile contains 2 data layers:

- *Map*: Land cover map with 11 classes, a total of approximately **117 GB**.
- *InputQuality*: Three band GeoTIFF providing three per pixel quality indicators of the Sentinel-1 and Sentinel-2 input data

The dataset can be accessed and/or downloaded in different ways:

5.3.1 Explore

5.3.1.1 WorldCover viewer

The [WorldCover viewer](#) is a simple web-mapping tool that allows users to navigate the globe visualizing the ESA WorldCover products without installing any software. Furthermore, it also allows users to compare the map with Sentinel-1 and Sentinel-2 median composites for 2020 & 2021, view land cover statistics per administrative area and provides the possibility to give feedback on the product. Finally, users can also use the viewer to download the WorldCover products either by administrative area, or customized region of interest.

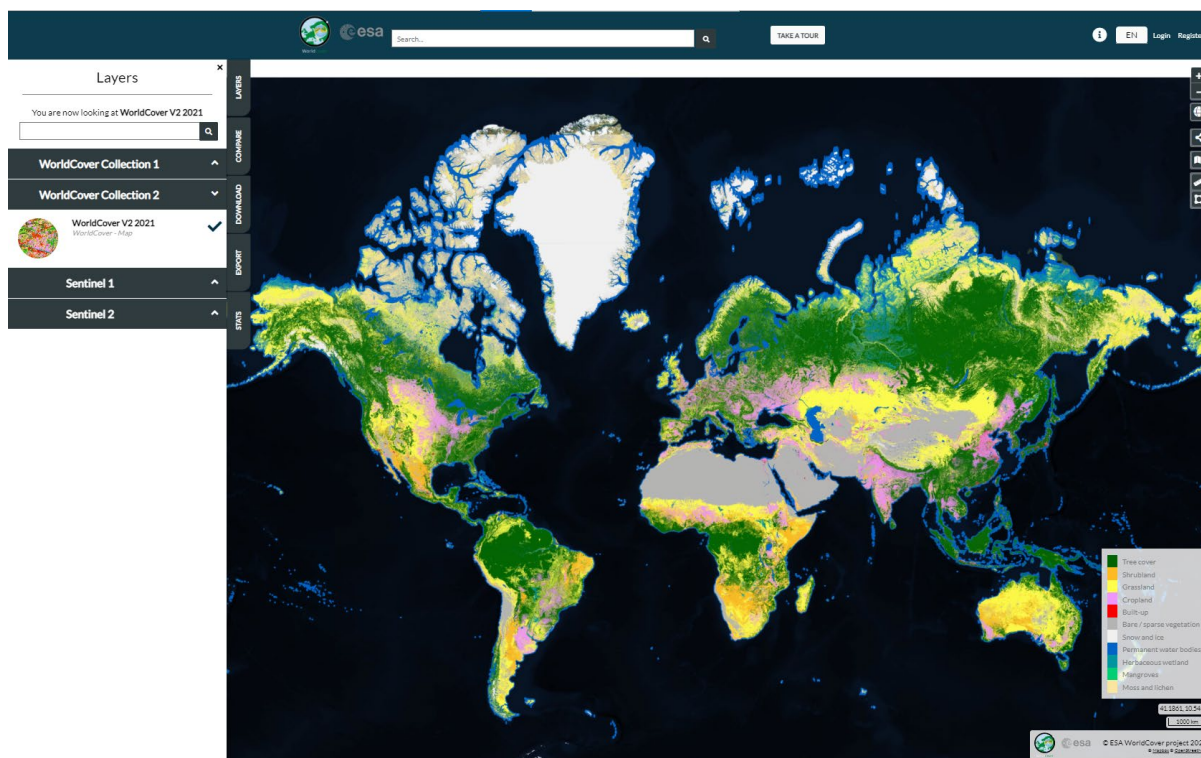


Figure 6: Screenshot of the WorldCover viewer

5.3.1.2 Alternative WorldCover viewer

As an alternative, the WorldCover 2020 and 2021 products can also be viewed at worldcover2020.esa.int and worldcover2021.esa.int hosted by ESA.

5.3.1.3 Google Earth Engine App

A dedicated [Earth Engine App](#) has been made which allows users to visualize the ESA WorldCover products and compare with Sentinel-1 and Sentinel-2 composites.

5.3.1.4 Web Map Services

The ESA WorldCover product can also be used within other websites or GIS clients by 'Web Map Services'. These services provide a direct link to the cached images and are the best option if you simply want to map the data and produce cartographic products. They are not suitable for analysis as the data are represented only as RGB images.

WMTS: <https://services.terrascope.be/wmts/v2>

WMS: <https://services.terrascope.be/wms/v2>

Layer: WORLDCOVER_2020_MAP & WORLDCOVER_2021_MAP

5.3.2 Data Download

The dataset can be downloaded from:

1. **WorldCover viewer** (Login required)
 - Navigate to the [WorldCover viewer](#)
 - Register for VITO's Terrascope platform (see the link in the top right)
 - Log in the [WorldCover viewer](#) with your Terrascope credentials

- From the 'Download' tab in the WorldCover viewer, zoom to an area of interest or draw a polygon to retrieve the list of tiles covering that area. The platform will zip the tiles and initiate the download.

2. Terrascope with Python (Login required)

Tiles can be downloaded programmatically using Python and the `terracatalogueclient` package. Please use your Terrascope credentials to download (see 1)

- Install the `terracatalogueclient`, see <https://vitobelgium.github.io/terracatalogueclient/installation.html> or run:

```
pip install --extra-index-url
https://artifactory.vgt.vito.be/api/pypi/python-packages/simple
terracatalogueclient
```

- Customize and run the following python script:

```
from terracatalogueclient import Catalogue

# create catalogue object and authenticate
catalogue = Catalogue().authenticate()

# search for products in the WorldCover collection
products =
catalogue.get_products("urn:eop:VITO:ESA_WorldCover_10m_2020_V1")

# download the products to the given directory
catalogue.download_products(products, "downloads")

from shapely.geometry import Polygon
from terracatalogueclient import Catalogue

### Authenticate to the Terrascope platform (registration required)
# create catalogue object and authenticate interactively with a browser
catalogue = Catalogue().authenticate()

# or authenticate with username and password
# catalogue = catalogue.authenticate_non_interactive(username, password)

### Filter catalogue
# search for all products in the WorldCover collection
# products =
catalogue.get_products("urn:eop:VITO:ESA_WorldCover_10m_2021_V2")

# or filter to a desired geometry, by providing it as an argument to
`get_products`

bounds = (3, 33, 15, 45)
geometry = Polygon.from_bounds(*bounds)
products =
catalogue.get_products("urn:eop:VITO:ESA_WorldCover_10m_2021_V2",
geometry=geometry)

### Download
# download the products to the given directory
catalogue.download_products(products, "downloads")
```

3. AWS S3 bucket

The products are hosted on the `esa-worldcover` S3 bucket in `eu-central-1` region. To download all the products:

- install the AWS command line interface, see <https://docs.aws.amazon.com/cli/latest/userguide/cli-chap-install.html> or open a python environment and run

```
pip install awscli.
```

- run

```
aws s3 sync s3://esa-worldcover/v200/2021/map/ /local/path --no-sign-request
```

(please modify `/local/path` to the desired download location)

- or alternatively use this python snippet to download a subset by country from AWS URLs

```
import geopandas as gpd

s3_url_prefix = "https://esa-worldcover.s3.eu-central-1.amazonaws.com"

# load natural earth low res shapefile
ne = gpd.read_file(gpd.datasets.get_path("naturalearth_lowres"))

# get AOI geometry (Italy in this case)
country = 'Italy'
geom = ne[ne.name == country].iloc[0].geometry

# load worldcover grid
url = f'{s3_url_prefix}/v100/2020/esa_worldcover_2020_grid.geojson'
grid = gpd.read_file(url)

# get grid tiles intersecting AOI
tiles = grid[grid.intersects(geom)]

# use requests library to download them
import requests
from tqdm.auto import tqdm # provides a progressbar

for tile in tqdm(tiles.ll_tile):
    url =
f"{s3_url_prefix}/v200/2021/map/ESA_WorldCover_10m_2021_v200_{tile}_Map.tif"
    r = requests.get(url, allow_redirects=True)
    out_fn = f"ESA_WorldCover_10m_2021_v200_{tile}_Map.tif"
    with open(out_fn, 'wb') as f:

        f.write(r.content)
```

4. Zenodo

- WorldCover 2020 v100 can be downloaded as a single `tar.gz` file from Zenodo: <https://zenodo.org/record/5571936#.YXA3ehpBxPY>

- WorldCover 2021 v200 can be downloaded as zipped macrotiles (60x60 degrees) from Zenodo: <https://doi.org/10.5281/zenodo.7254221>

5. worldcover2020.esa.int & worldcover2021.esa.int

The 2020 & 2021 datasets can be downloaded as 18 60x60 degree macro tiles, whereby each macro tile contains a zipped version of all covered 3x3 degree tiles

Please note that the *Map* data layer can be downloaded from all 5 options. The *InputQuality* layer is so far only available from options 1 or 2.

5.3.3 Google Earth Engine

The WorldCover data can also be accessed and used in the Google Earth Engine platform - for more information see [here](#).

- The WorldCover 2020 data is available with Asset ID `ESA/WorldCover/v100`
- The WorldCover 2021 data is available with Asset ID `ESA/WorldCover/v200`

5.4 Supporting files

5.4.1 Symbology

The WorldCover map layer contains a colormap which will display the files in desktop GIS tools (such as QGIS or ArcGIS) using the symbology that has been used in the WorldCover viewer. However, these colormaps do not contain the labels for the values. These can be added to the files by using the symbology files for either [QGIS](#) or [ArcGIS](#).

- To use the *.qml file in QGIS: Double click on the layer to open the Layer properties dialog. At the bottom of the dialog, click Style | Load Style... Navigate to the location of the *.qml file and click Open.
- To use the *.lyr file in ArcGIS: Double click on the layer to open the Layer properties dialog. Click on the Symbology tab and change the rendered to Unique Values. Click 'Yes' when prompted to build an attribute table. Click on the Import Symbology button in the top right. Navigate to the location of the *.lyr file and click Add

Besides the standard WorldCover colormap also colormap files with a symbology used in the CCI land cover maps is provided. [QGIS](#) or [ArcGis](#)

There are no symbology files for the InputQuality layer.

5.5 Contact

More information and documentation about the product is available from the WorldCover web site at <https://esa-worldcover.org>

If you have any feedback on the ESA WorldCover product please contact remotesensing@vito.be

6 Validation

The WorldCover 2021 v200 product was statistically validated using an independent validation dataset. The validation followed the CEOS (the Committee on Earth Observation Satellites) Validation guidelines (Stage 4).

The statistical validation used the multi-purpose Global Land Cover Validation dataset developed for the Copernicus Global Land Service- Land Cover 100 product (the CGLS-LC validation dataset) which is suitable for validation of 10 m resolution global land cover maps. This dataset was updated for the reference year 2021 by revisiting random and targeted (for land cover change) subsets.

The validation dataset includes more than 21 000 primary sampling units (PSUs) spread over seven (sub)continents selected based on a stratified random sampling (Figure 7). Each PSU consists of 100 secondary sample units (SSU) which correspond to Sentinel-2 10 m resolution pixels.

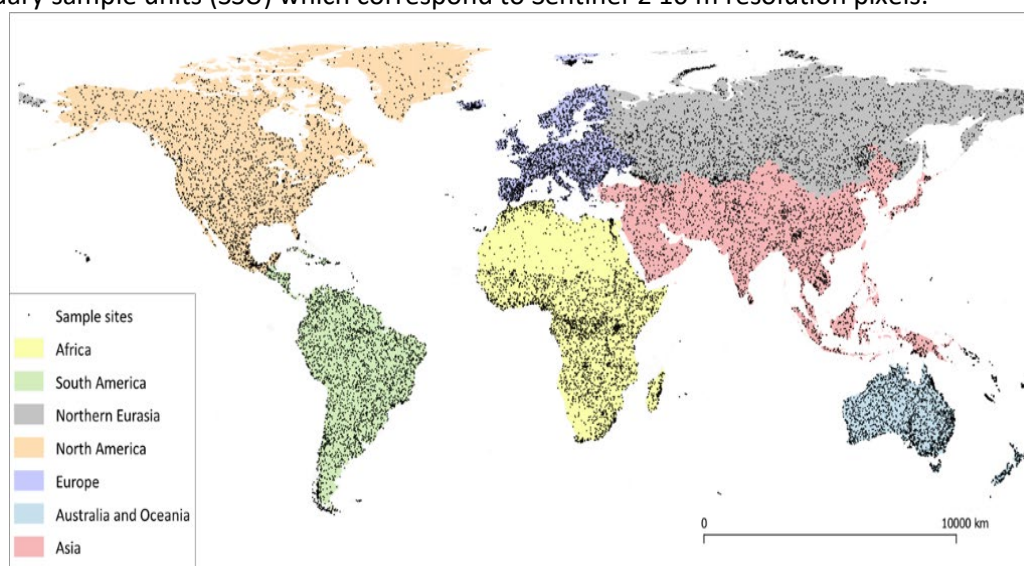


Figure 7: Spatial distribution of all validation sample sites for different (sub) continents

The validation results showed that the global overall accuracy of the WorldCover 2021 v200 product is 76.7 ± 0.5 . In terms of class-specific accuracies at the global scale, grassland, cropland, bare/sparse vegetation, and permanent water classes have slightly higher accuracies for the WorldCover 2021 v200 compared to the WorldCover 2020 v100; Built-up, herbaceous wetlands, and lichen/moss classes have seen a significant increase in the accuracies.

Overall accuracies at the continental level are above 72%, with the highest accuracy of 82.1% for Asia and the lowest accuracy of 72.5% for Oceania-Australia and Eurasia (Table 4). Compared to the WorldCover 2020 v100 product, all continents have an improved overall accuracy in the WorldCover 2021 v200. The most increase in accuracy was observed in North America, followed by Africa and Asia.

Table 4: Overall accuracy for the WorldCover 2021 v200 product at the continental level and sample sites used (SSU- secondary sample units, PSU – primary sample units)

	Overall accuracy	Total SSU	Total PSU
Global	76.7 +/- 0.5	2,162,366	21,624
Africa	76.5 +/- 1.3	359,900	3,599
Europe	77.9 +/- 1.0	311,800	3,118
Eurasia	72.5 +/- 1.3	300,271	3,003
Asia	82.1 +/- 1.0	306,400	3,064

Oceania	72.5 +/- 1.3	296,100	2,961
North America	74.6 +/- 1.2	287,995	2,880
South America	77.9 +/- 1.1	299,900	2,999

Detailed information on the validation of this product and comparison results can be found in **the product validation report** available at esa-worldcover.org/en/data-access. Overall, the WorldCover 2021 v200 product shows promising improvements in characterizing the World's land cover at 10 m resolution.

7 References

Abatzoglou, J.T., Dobrowski, S.Z., Parks, S.A., Hegewisch, K.C. (2018). Terraclimate, a high-resolution global dataset of monthly climate and climatic water balance from 1958-2015, *Scientific Data* 5(1), 1-12. [doi:10.1038/sdata.2017.191](https://doi.org/10.1038/sdata.2017.191)

Arino, O., Bicheron, P., Achard, F., Latham, J., Witt, R., Weber, J.L. (2008). GlobCover the most detailed portrait of Earth. *ESA Bulletin*, 136, 25-31.

Buchhorn, M., Lesiv, M., Tsendbazar, N.-E., Herold, M., Bertels, L., Smets, B. (2020). Copernicus Global Land Cover Layers—Collection 2. *Remote Sensing* 12(6), 1044. [doi:10.3390/rs12061044](https://doi.org/10.3390/rs12061044)

Buchhorn, M., Bertels, L., Smets, B., De Roo, B., Lesiv, M., Tsendbazar, N. E., Masiliunas, D., & Li, L. (2020). Copernicus Global Land Service: Land Cover 100m: Version 3 Globe 2015-2019: algorithm theoretical basis document. [10.5281/zenodo.3938968](https://doi.org/10.5281/zenodo.3938968)

Bunting, P., Rosenqvist, A., Hilarides, L., Lucas, R.M., Thomas, N., Tadono, T., Worthington, T.A, Spalding, M., Murray, N.J., Rebelo, L.M. (2022). Global Mangrove Watch Extent Change 1996-2020: Global Mangrove Watch Version 3.0. *Remote Sensing* 14(15): 3654. [doi:10.3390/rs14153657](https://doi.org/10.3390/rs14153657).

Corbane, C., Sabo, F., Politis, P., Syrris, V. (2020). GHS-BUILT-S2 R2020A - built-up grid derived from Sentinel-2 global image composite for reference year 2018 using Convolutional Neural Networks (GHS-S2Net). European Commission, Joint Research Centre (JRC) PID: <http://data.europa.eu/89h/016d1a34-b184-42dc-b586-e10b915dd863>. [doi:10.2905/016D1A34-B184-42DC-B586-E10B915DD863](https://doi.org/10.2905/016D1A34-B184-42DC-B586-E10B915DD863).

Corbane, C., Syrris, V., Sabo, F., Politis, P., Meclchiorri, M., Pesaresi, M., Soille, P., Kemper, T. (2021). Convolutional neural networks for global human settlements mapping from Sentinel-2 satellite imagery. *Neural Computing and Applications* 33. [doi:10.1007/s00521-020-05449-7](https://doi.org/10.1007/s00521-020-05449-7).

Dinerstein, E., Olson, D., Joshi, A., Vynne, C., Burgess, N. D., Wikramanayake, E., Hahn, N., Palminteri, S., Hedao, P., Noss, R., Hansen, M., Locke, H., Ellis, E. C., Jones, B., Barber, C. V., Hayes, R., Kormos, C., Martin, V., Crist, E., Sechrest, W., Price, L., Baillie, J. E. M., Weeden, D., Suckling, K., Davis, C., Sizer, N., Moore, R., Thau, D., Birch, T., Potapov, P., Turubanova, S., Tyukavina, A., de Souza, N., Pintea, L., Brito, J. C., Llewellyn, O. A., Miller, A. G., Patzelt, A., Ghazanfar, S. A., Timberlake, J., Klöser, H., Shennan-Farpón, Y., Kindt, R., Lillesø, J. B., van Breugel, P., Graudal, L., Vogele, M., Al-Shammari, K. F., Saleem, M. (2017). An Ecoregion-Based Approach to Protecting Half the Terrestrial Realm, *BioScience*, 67(6), 534–545. [doi:10.1093/biosci/bix014](https://doi.org/10.1093/biosci/bix014)

ESA. Land Cover CCI Product User Guide Version 2. Tech. Rep. (2017). Available at: maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf.

Fahrland, E., Jacob, P., Schrader, H., Kahabka, H. (2019). Copernicus DEM Product Handbook. AIRBUS Defence and Space, Campaign ID: GEO.2018-1988-2, Version 1.0, pp. 27.

Prokhorenkova, L., Gusev, G., Vorobev, A., Dorogush, A. V., Gulin, A. (2018). CatBoost: unbiased boosting with categorical features. *Advances in neural information processing systems*, 6638-6648.

Marconcini, M., Metz-Marconcini, A., Esch, T., Gorelick, N. (2021). Understanding Current Trends in Global Urbanisation – The World Settlement Footprint suite. *GI_Forum*, 1, 33-38. [doi:10.1553/giscience2021_01_s33](https://doi.org/10.1553/giscience2021_01_s33).

OpenStreetMap contributors. (2021) Planet dump retrieved from <https://planet.openstreetmap.org>.

Zanaga, D., Van De Kerchove, R., De Keersmaecker, W., Souverijns, N., Brockmann, C., Quast, R., Wevers, J., Grosu, A., Paccini, A., Vergnaud, S., Cartus, O., Santoro, M., Fritz, S., Georgieva, I., Lesiv, M., Carter, S., Herold, M., Li, Linlin, Tsendbazar, N.E., Ramoino, F., Arino, O. (2021). ESA WorldCover 10 m 2020 v100. [doi:10.5281/zenodo.5571936](https://doi.org/10.5281/zenodo.5571936).