

J R C T E C H N I C A L R E P O R T S

A Pan-European Data Set for hydrological modelling

*Description of the input layers
for the hydrological
LISFLOOD model*

Peter Burek, Alessandra Bianchi, Alessandro Gentile

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Contact information

Dr. Peter Burek

Address: Joint Research Centre, Via Enrico Fermi 2749, TP 261, 21027 Ispra (VA), Italy

E-mail: peter.burek@ec.europa.eu

Tel.: +39 0332 78 5815

Fax: +39 0332 78 6653

<http://ies.jrc.ec.europa.eu/the-institute/units/water-resources.html>

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1 Introduction

This technical report describes the static input layers for the LISFLOOD model. The data set contains gridded numerical information related to topography, channel geometry, land cover and soil characteristics at a pan-European scale. This report gives a summary of the source geo-spatial data sets, the applied methodology and the characteristics of the resulted data.

A complete set of static input maps covering the whole of Europe and parts of Asia and Africa have been compiled at 1km and 5km spatial resolution. The LISFLOOD model is implemented in the PCRaster Environmental Modelling language (Wesseling et al., 1996). PCRaster is a raster GIS environment that has its own binary format raster called PCRaster map which are readable by QuantumGIS and ArcGIS. The result maps are therefore provided as PCRaster maps, as .tif and the result maps on 5km also as netCDF files.

The LISFLOOD model is a hydrological rainfall-runoff and channel routing model that has been developed by the Joint Research Centre (JRC) of the European Commission. The model is used for the modelling of hydrological processes for large (and often trans-national) catchments. A description about which data set is needed for which process is given in Burek et al., 2013.

2 Projection: ETRS-LAEA

Annoni 2005 proposed in the framework of INSPIRE for rasterised cartographic products such as remote sensed imagery the projection the Lambert Azimuthal Equal Area (LAEA) projection based on the European Terrestrial Reference System (ETRS) 1989. The main advantages are:

- Suitability for the whole European continent (25W-45E, 32N-72N).
- Equal area representation of a given cell (pixel) throughout the raster (image/map).
- Tolerable distortion of shape.

The European Terrestrial Reference System 1989 (ETRS89) is the geodetic datum for pan-European spatial data collection, storage and analysis. This is based on the GRS80 ellipsoid and is the basis for a coordinate reference system using ellipsoidal coordinates. For many pan-European purposes a plane coordinate system is preferred. But the mapping of ellipsoidal coordinates to plane coordinates cannot be made without distortion in the plane coordinate system. Distortion can be controlled, but not avoided. For many purposes the plane coordinate system should have minimum distortion of scale and direction. There is some distortion (angles, distances) intrinsic to the grid (e.g. up to 3% in Turkey for ETRS-LAEA).

For pan-European statistical mapping at all scales or for other purposes where true area representation is required, the ETRS89 Lambert Azimuthal Equal Area Coordinate Reference System (ETRS-LAEA) is recommended.

The ETRS89 Lambert Azimuthal Equal Area Coordinate Reference System (ETRS-LAEA) is a single projected coordinate reference system for all of the pan-European area. It is based on the ETRS89 geodetic datum and the GRS80 ellipsoid. Its defining parameters are given in Table 2-1 following ISO 19111 Spatial referencing by coordinates. With these defining parameters, locations North of 25° have positive grid northing and locations eastwards of 30° West longitude have positive grid easting.

Table 2-1: ETRS-LAEA Description
 from <http://spatialreference.org/ref/epsg/etrs89-etrs-laea>

Entity	Value
CRS ID	ETRS-LAEA
CRS alias	ETRS89 Lambert Azimuthal Equal Area CRS
CRS valid area	Europe
CRS scope	CRS for pan-European statistical mapping at all scales or other purposes where true area representation is required
Datum ID	ETRS89
Datum alias	European Terrestrial Reference System 1989
Datum type	geodetic
Datum realization epoch	1989
Datum valid area	Europe / EUREF
Datum scope	European datum consistent with ITRS at the epoch 1989.0 and fixed to the stable part of the Eurasian continental plate for georeferencing of GIS and geokinematic tasks
Datum remarks	see Boucher, C., Altamimi, Z. (1992): The EUREF Terrestrial Reference System and its First Realizations. Veröffentlichungen der Bayerischen Kommission für die Internationale Erdmessung, Heft 52, München 1992, pp 205-213 - or - ftp://lareg.ensg.ign.fr/pub/euref/info/guidelines
Prime meridian ID	Greenwich
Prime meridian Greenwich longitude	0°
Ellipsoid ID	GRS 80
Ellipsoid alias	New International
Ellipsoid semi-major axis	6 378 137 m
Ellipsoid shape	true
Ellipsoid inverse flattening	298.257222101
Ellipsoid remarks	see Moritz, H. (1988): Geodetic Reference System 1980. Bulletin Geodesique, The Geodesists Handbook, 1988, Internat. Union of Geodesy and Geophysics
Coordinate system ID	LAEA
Coordinate system type	projected
Coordinate system dimension	2
Coordinate system axis name	Y
Coordinate system axis direction	North
Coordinate system axis unit identifier	metre
Coordinate system axis name	X
Coordinate system axis direction	East
Coordinate system axis unit identifier	metre
Operation ID	LAEA
Operation valid area	Europe
Operation scope	for pan-European statistical mapping at all scales or other purposes where true area representation is required
Operation method name	Lambert Azimuthal Equal Area Projection
Operation method formula	US Geological Survey Professional Publication 1395, "Map Projection – A Working Manual" by John P. Snyder.
Operation method parameters number	4
Operation parameter name	latitude of origin
Operation parameter value	52° N
Operation parameter name	longitude of origin
Operation parameter value	10° E
Operation parameter remarks	
Operation parameter name	false northing
Operation parameter value	3 210 000.0 m
Operation parameter remarks	
Operation parameter name	false easting
Operation parameter value	4 321 000.0 m
Operation parameter remarks	

Spatial reference: EPSG Projection 3035 - ETRS89 / ETRS-LAEA
(from <http://spatialreference.org/ref/epsg/etrs89-etrs-laea>)

```
PROJCS["ETRS89 / ETRS-LAEA",  
  GEOGCS["ETRS89",  
    DATUM["European_Terrestrial_Reference_System_1989",  
      SPHEROID["GRS 1980",6378137,298.257222101,  
        AUTHORITY["EPSG","7019"]],  
      AUTHORITY["EPSG","6258"]],  
    PRIMEM["Greenwich",0,  
      AUTHORITY["EPSG","8901"]],  
    UNIT["degree",0.01745329251994328,  
      AUTHORITY["EPSG","9122"]],  
      AUTHORITY["EPSG","4258"]],  
    UNIT["metre",1,  
      AUTHORITY["EPSG","9001"]],  
    PROJECTION["Lambert_Azimuthal_Equal_Area"],  
    PARAMETER["latitude_of_center",52],  
    PARAMETER["longitude_of_center",10],  
    PARAMETER["false_easting",4321000],  
    PARAMETER["false_northing",3210000],  
    AUTHORITY["EPSG","3035"],  
    AXIS["X",EAST],  
    AXIS["Y",NORTH]]]
```

Proj4 format:

```
Proj4js.defs["EPSG:3035"] = "+proj=laea +lat_0=52 +lon_0=10 +x_0=4321000 +y_0=3210000  
+ellps=GRS80 +units=m +no_defs"
```

ArcGis format:

```
PROJCS["ETRS89 / ETRS-  
LAEA",GEOGCS["ETRS89",DATUM["D_ETRS_1989",SPHEROID["GRS_1980",6378137,298.257222  
101]],PRIMEM["Greenwich",0],UNIT["Degree",0.017453292519943295]],PROJECTION["Lambert  
_Azimuthal_Equal_Area"],PARAMETER["latitude_of_origin",52],PARAMETER["central_meridian",  
10],PARAMETER["false_easting",4321000],PARAMETER["false_northing",3210000],UNIT["Meter  
",1]]]
```

2.1 Map extend:

Top: 5500000 (including Scandinavia)
Left: 2500000 (including the Iberian Peninsula)
Right: 7500000 (including Turkey)
Bottom: 750000 (including the gauge Assuit in Egypt)

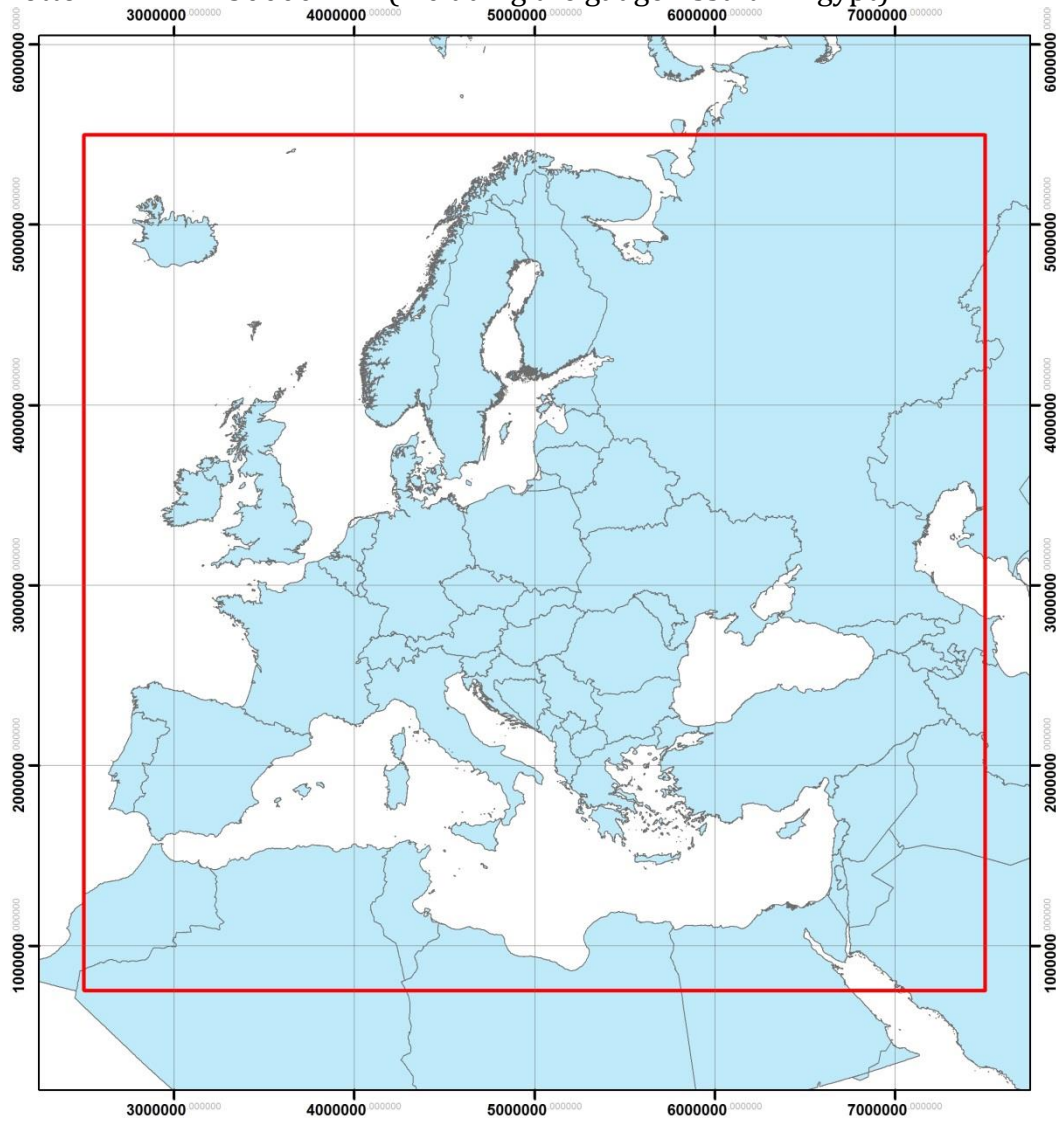


Figure 2-1: Map extent for pan-European data set

2.2 Mask map

The mask map defines the standard map in different resolution (100m, 1km, 5km). All data sets need to provide data for pixels defined in this mask map. We decided to use the combined 100m resolution Land cover data set (Corine 2006, Corine 2000 and Global Land Cover) (see chapter about Land cover) as mask map.

Based on the Land cover data set, a shape file was created (mask.shp) and the the 100m mask map was upscaled to 1km and 5km with the following rule:

- The boolean mask map at 1km or 5km will have a “True” cell, if it includes a single 100m pixel True” pixel.

The percentage of “True” 100m pixels inside a 1km or 5km cell is stored as mask_1km_percent.map and mask_5km_percent.map

Figure 2-1 shows that according to the mask map 5km Sicilian is connected to Calabria (left side of Fig 1). This is, because every 5x5km cell becomes a “True” value if there is any 100x100m fine resolution “True” pixel covered. At its narrowest point the Strait of Messina is 3.1km width, therefore Sicily become connected to Calabria. The right side of Figure 2-2Fig. shows the percentage of 100x100m in a 5x5km cell.

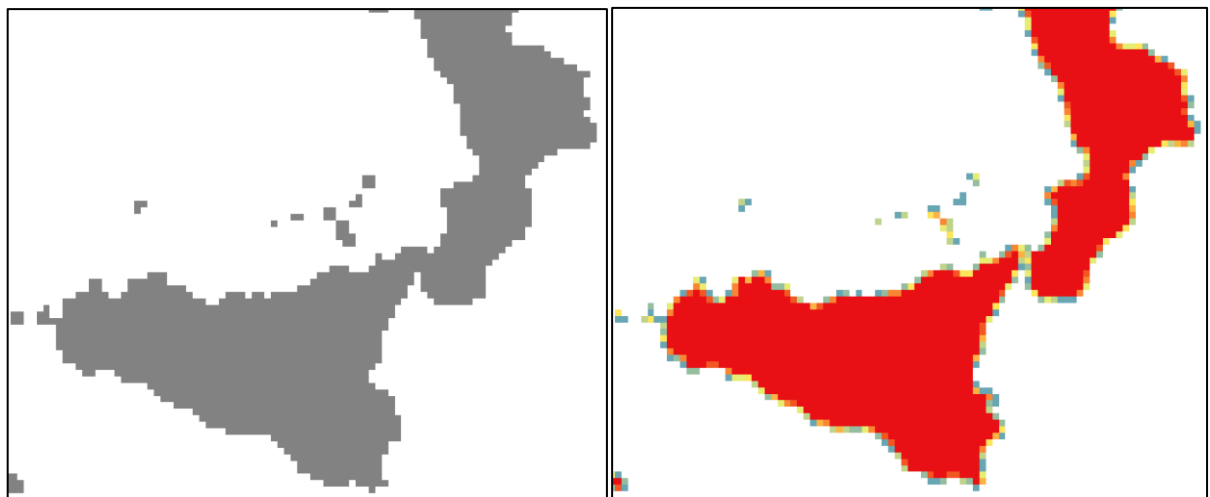


Figure 2-2: Mask 5km and mask 5km percentage map

3 Land cover

3.1 Data

Corine land cover 2006 refined

Corine land cover data set 2006 refined by Batista et al. 2012 based on Corine CLC 2006, version 13. The CORINE data classifies the land cover types into 44 classes. The spatial resolution of the gridded CLC2000 is 100 m. The data is available in the Lambert Azimuthal Equal Area (LAEA) projection with the ETRS 1989 datum.

The objective of Batista et al. 2012 was to improve the spatial detail of CLC 2006 by incorporating land use/cover information present in finer thematic maps available for Europe such as the CLC change map, Soil Sealing Layer, Tele Atlas Spatial Database, Urban Atlas, and Water Bodies Data from the Shuttle Radar Topography Mission. The refine data set is also used to be consistent with the work of Lavalle et al. (2011) on land use modelling.

Corine land cover 2000

Corine land cover 2000 - Version 16 (04/2012) - Raster data on land cover for the CLC2000, 100m resolution. Because Corine 2006 does not cover Greece, the Corine data set 2000 was used here.

GlobCover 2009

The GlobCover2009 (GC2009) database (Arino 2010) has been chosen to extend the missing areas of the European land cover database. The GC2009 product and documentation are available from the website of the European Space Agency (ESA).

The GC2009 classification differs from the classes applied in CORINE. The source data is defined by geographic coordinates (Lat/Lon, WGS84). The spatial resolution is $\sim 1/3$ km at the Equator (0.00277 decimal degrees).

Figure 3-1 shows the geographical coverage of the three different data sets.

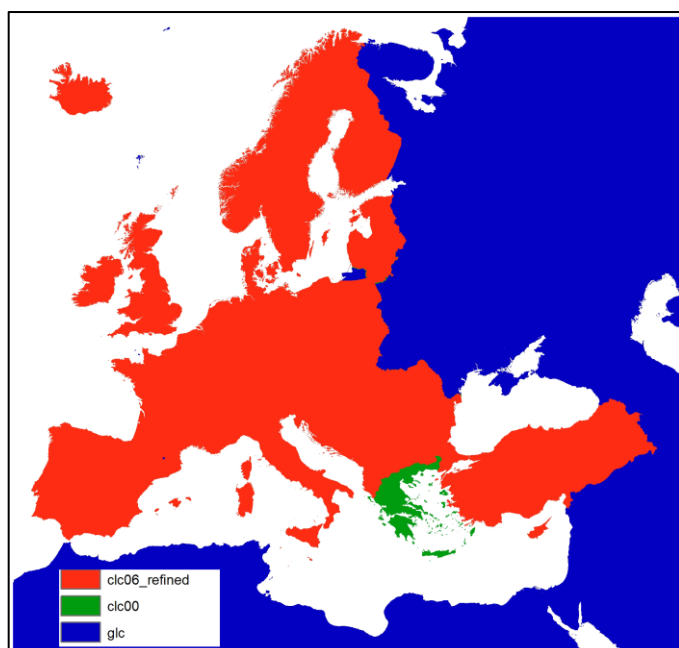


Figure 3-1: Geographical coverage of CLC 2006, CLC 2000 and GC2009

Forest coverage

Two pan-European forest maps with a resolution of 25m were produced by the European Commission's Joint Research Centre for the years 2000 and 2006 (et al. 2011). Both forest maps were derived from high-resolution, optical satellite imagery using an automatic processing technique, while the forest map from 2006 was further refined to map forest types using MODIS satellite imagery. For creating the forest fraction of each cell on 1km and 5km the Pan-European Forest/Non-Forest Map 2006 (FMAP2006) is used. FMAP2006 covers the EU-27 and Norway, Switzerland, Lichtenstein, Albania, Croatia, Macedonia, Montenegro, Serbia, Turkey. The maps included a forest, non-forest and water class.

Impermeable surface fraction

Soil Sealing (or imperviousness) is an EEA layer with European coverage. Its main use is the characterisation of the human impact on the environment. Multi-sensor and bi-temporal, orthorectified satellite imagery (IMAGE2006) was used to derive soil sealing data covering 38 countries of Europe (EEA 2013, Kopecky and Kahabka 2009). A Raster data set of built-up and non built-up areas including continuous degree of soil sealing ranging from 0 - 100%.

3.2 Methodology

Merging the three land cover datasets

CLC2006 and CLC2000 are using the same LAEA ETRS1989 projection and the same nomenclature of Corine classes. Therefore merging can be done by superposition the CLC2000 with the CLC2006 data set.

To include the GC2009 data set, several steps were necessary:

1. Because there is no distinguish between inland waters (lakes, rivers) and marine waters, a buffer was created inside the mask map. Every water body inside the buffer zone was declared as marine water.
2. GC2009 was re-projected to LAEA ETRS89
3. Reclassified using a statistical correspondence matrix. Table 3-1 shows the conversion table between GC2009 and Corine.

Table 3-1: Conversion table between GlobCover 2009 and CORINE land cover

Code and land cover type GlobCover 2009		Code and land cover type Corine 2000 & 2006	
11	Post-flooding or irrigated croplands (or aquatic)	13	Permanently irrigated land
14	Rainfed croplands	12	Non-irrigated arable land
20	Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)	12	Non-irrigated arable land
30	Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)	12	Non-irrigated arable land
40	Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (>5m)	25	Mixed forest
50	Closed (>40%) broadleaved deciduous forest (>5m)	23	Broad-leaved forest
60	Open (15-40%) broadleaved deciduous forest/woodland (>5m)	27	Moors and heathland
70	Closed (>40%) needleleaved evergreen forest (>5m)	24	Coniferous forest
90	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)	24	Coniferous forest
100	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)	25	Mixed forest
110	Mosaic forest or shrubland (50-70%) / grassland (20-50%)	27	Moors and heathland
120	Mosaic grassland (50-70%) / forest or shrubland (20-50%)	23	Broad-leaved forest
130	Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m)	29	Transitional woodland-shrub
140	Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses)	18	Pastures
150	Sparse (<15%) vegetation	32	Sparsely vegetated areas
160	Closed to open (>15%) broadleaved forest regularly flooded (semi-permanently or temporarily) - Fresh or brackish water	37	Salt marshes
170	Closed (>40%) broadleaved forest or shrubland permanently flooded - Saline or brackish water	37	Salt marshes
180	Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil - Fresh, brackish or saline water	35	Inland marshes
190	Artificial surfaces and associated areas (Urban areas >50%)	2	Discontinuous urban fabric
200	Bare areas	31	Bare rocks
210	Water bodies	41	Water bodies
220	Permanent snow and ice	34	Glaciers and perpetual snow

Result is a merged land cover grid at 100m resolution where the GC2009 is overlaid by the CLC2000 and CLC2006 using the Corine legend.

Dismissing land cover classes which are not modeled

These Corine land use classes are set to NoData

39	Maritime wetlands	Intertidal flats
42	Marine waters	Coastal lagoons
43	Marine waters	Estuaries
44	Marine waters	Sea and ocean

Rescaling from 100m resolution to 1km and 5km

Land cover classes are nominal classes. In contrast to scalar classes like for example elevation it is not possible to calculate the mean or median values. Therefore the method of spatially dominant value is used. The method finds the majority value (the value that appears most often) for the specified area such as the grid size of the resampled data.

A spatial distribution at 1km and 5km resolution of percentage of each Corine class is given. Addition of all percentage land cover grids results in 100%.

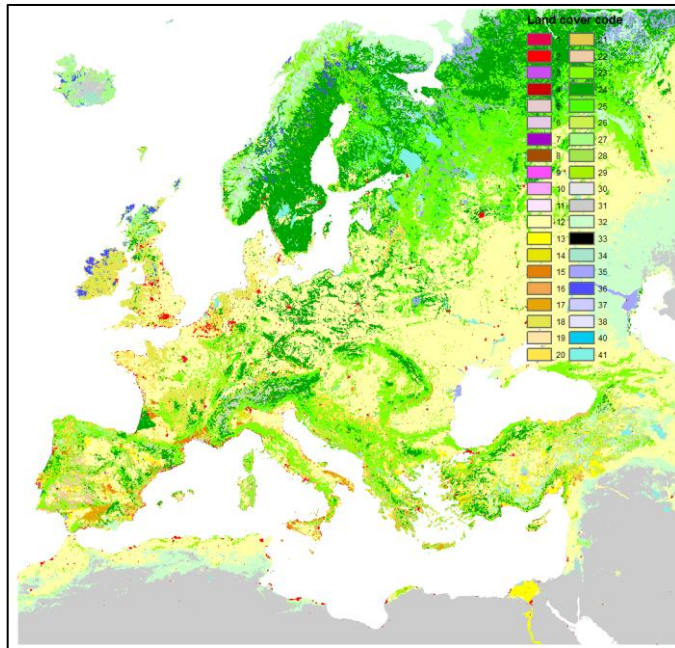


Figure 3-2: 5km resolution dominant land cover based on the combined land cover based on CLC20006, GLC 2000 and GC2009.

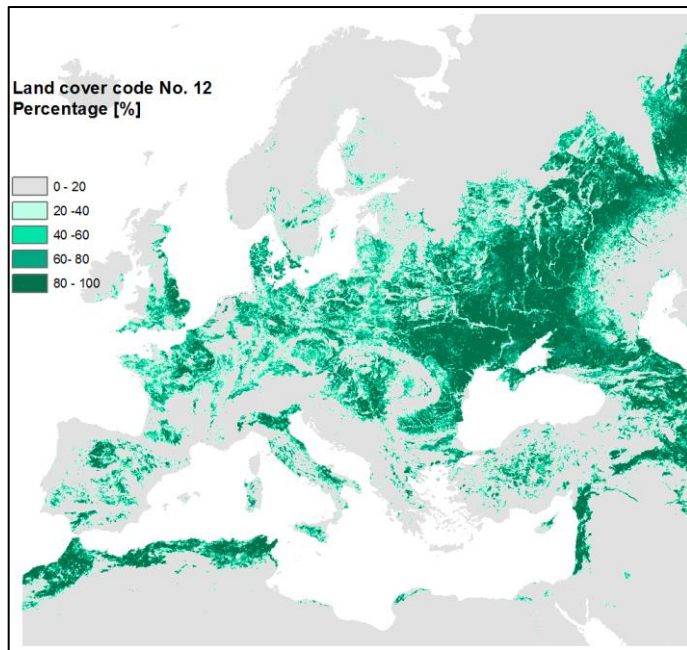


Figure 3-3: 5km resolution of percentage of Corine class 12 (Non-irrigated arable land)

Percentage of forest coverage

This map contains the forest fraction for each cell. Values range from 0 (no forest at all) to 1 (pixel is 100% forest).

The forest fraction maps are based for EU-28 and Norway, Switzerland, Lichtenstein, Albania, Macedonia, Montenegro, Serbia, Turkey on the FMAP2006 25m resolution grids. For the area outside of the FMAP2006, the percentage of CORINE classes 'broad-leaved forest' (23), 'coniferous forest' (24) and 'mixed forest' (25) were summed up.

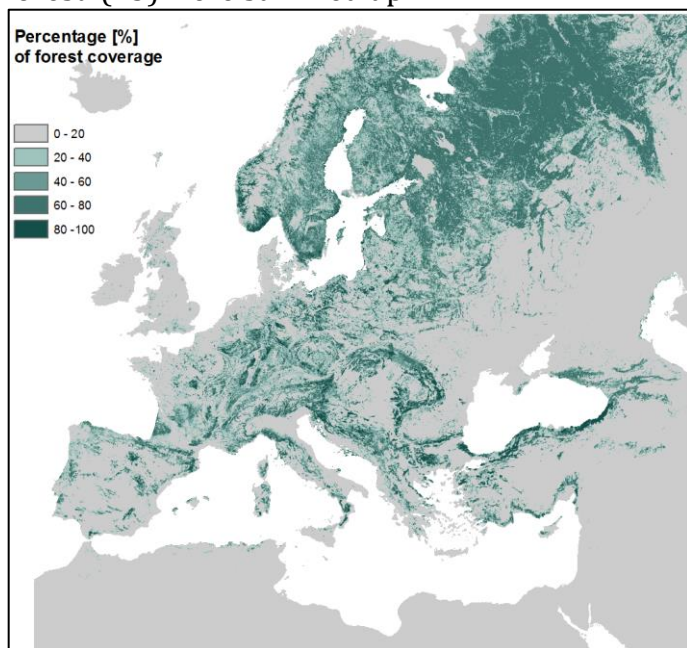


Figure 3-4: 5km resolution of percentage of forest coverage

Percentage of impermeable surface

This map contains the sealed (impermeable) fraction for each cell. Values range from 0 (no sealing) to 1 (pixel is 100% sealed). For 38 countries it is based on the 100m resolution soil Sealing EEA layer. For the area outside of the EEA layer the Corine classes in table x are taken, an impermeability was assigned based on Laguradia, 2005 and the average impermeability for 1km and 5km was calculated.

Table 3-2: Impermeability based on Corine classes

Corine code and description		Sealed Area [%]
1	Continuous urban fabric	0.75
2	Discontinuous urban fabric	0.50
3	Industrial or commercial units	0.75
4	Road and rail networks	0.50
5	Port areas	0.75
6	Airports	0.50
7	Mineral extraction sites	0.50
8	Dump sites	0.25
9	Construction sites	0.25
10	Green urban areas	0.25
11	Sport and leisure facilities	0.25
31	Bare rocks	0.75
34	Glaciers and perpetual snow	0.75

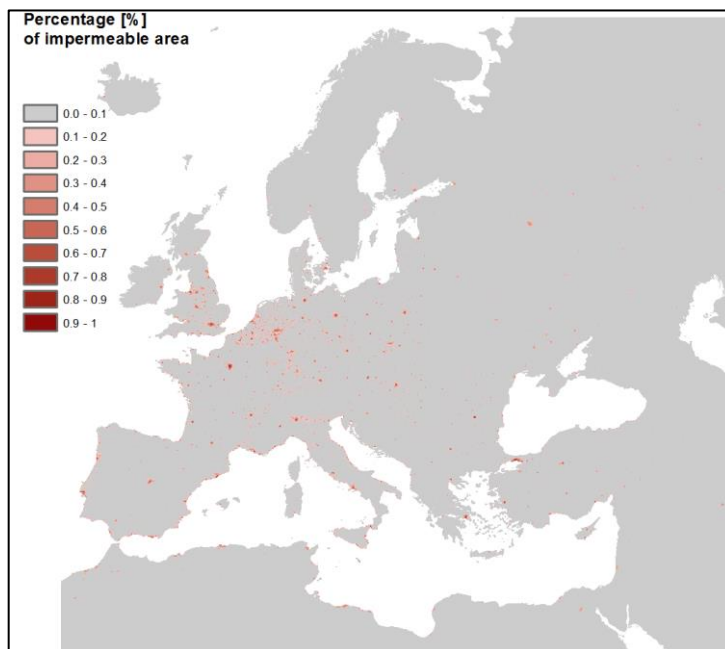


Figure 3-5: 5km resolution of percentage of impermeable (sealed) area

Percentage of water coverage

For calculating the percentage of inland waters (lakes, rivers) the Corine classes in table x are taken, a water coverage per land cover class was assigned and the average water coverage for 1km and 5km was calculated.

Table 3-3: Water coverage based on Corine classes

Corine code and description		Water coverage [%}
35	Inland marshes	0.5
36	Peat bogs	0.5
37	Salt marshes	0.75
38	Salines	1
40	Water courses	1
41	Water bodies	1

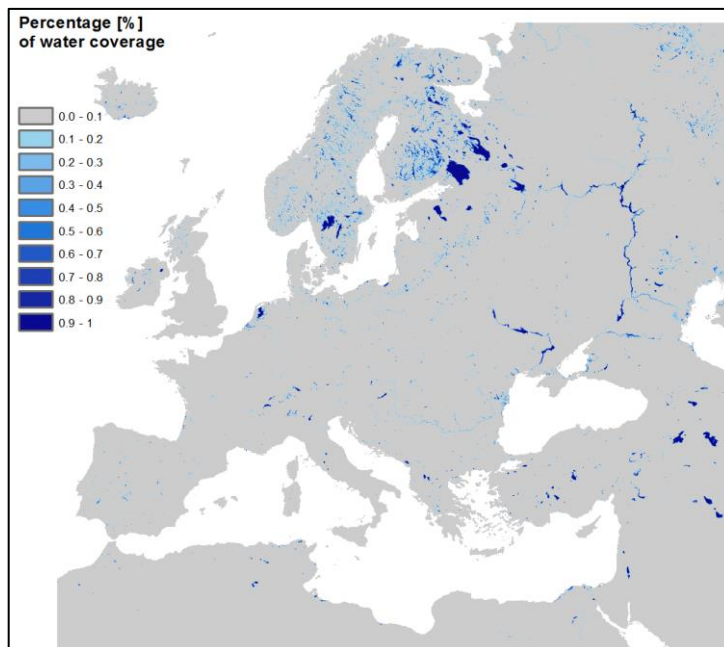


Figure 3-6: 5km resolution of percentage of inland water coverage

Land cover depending maps

The land cover depending map's like crop coefficient, crop group number and manning's surface roughness are calculated using the land cover maps at 100m resolution together with a lookup table (see Annex 4). The lookup table is used from LaGuardia 2005. As LISFLOOD simulates forest land cover separately, each map needs a non forest and a forest version.

Crop coefficient

Crop coefficient is a simply ration between the potential (reference) evapotranspiration rate [mm day⁻¹] and the potential evaporation rate of a specific crop. E.g. rice fields have a higher transpiration rate than the reference crop, therefore the crop coefficient of rice fields is 1.2.

For forest a unique value of 1.0 is taken.

Crop group number

Crop group number is used to calculate the fraction of soil moisture between soil moisture at field capacity (pF₂, 100 cm) [mm water slice] and soil moisture at wilting point (pF_{4.2}, 10^{4.2} cm) that can be extracted from the soil without reducing the transpiration rate. The value of p is a function of vegetation type and potential evapotranspiration. The crop group number is proportional to p. E.g. Olive groves are adapted to dry climate, therefore they can extract more water from drying out soil than e.g. rice. The crop group number of olive groves is 4 and of rice fields is 1.

For forest a unique value of 3.5 is taken.

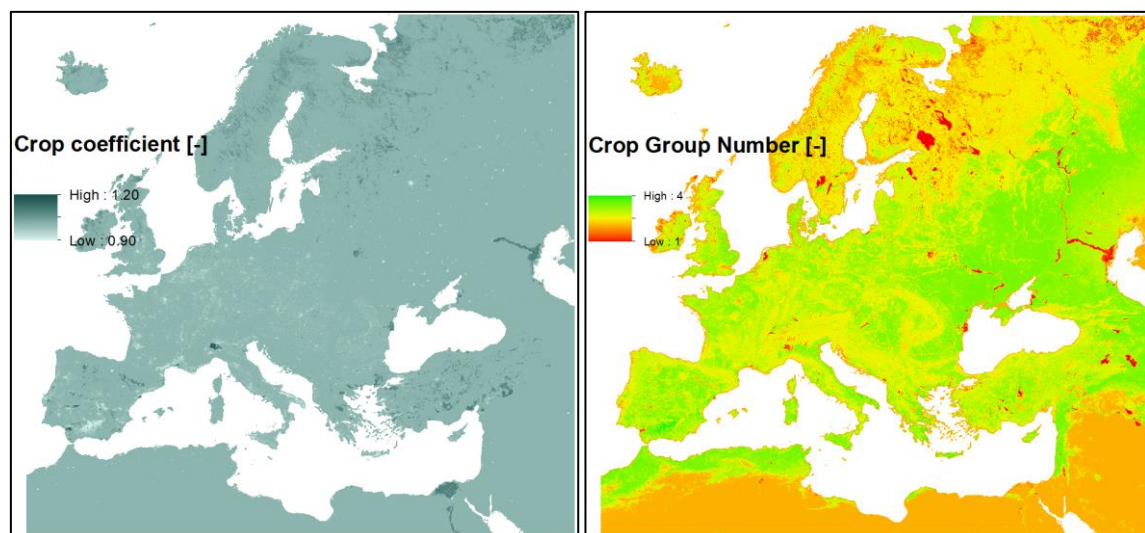


Figure 3-7: Crop coefficient and Crop Group Number

Manning's roughness

The kinematic wave approach is using the Manning's formula, an empirical formula for open channel flow, or free-surface flow driven by gravity. The Manning's roughness coefficient is reciprocal proportional to the cross-sectional average velocity [m/s]. A lower Manning's results in a faster responding time at the outlet.

For forest a unique value of 0.3 is taken.



Figure 3-8: Manning's surface roughness at 5km resolution

4 Digital elevation model and channel network

4.1 Data

DGM – Shuttle Radar Topography Mission (SRTM)

The Shuttle Radar Topography Mission (SRTM) is a digital elevation model from 56° S to 60° N in a three arcsecond (90 m) resolution. The project was a joint endeavour of NASA, the U.S. National Geospatial-Intelligence Agency (NGA), and the German and Italian Space Agencies, and flew in February 2000. It used dual radar antennas to acquire interferometric radar data (IFSAR), processed to digital topographic data at 1 arc-sec resolution (Farr et al., 2007).

The original data contains small holes of no data over water bodies, mountainous regions and desertic regions. Jarvis et al. 2008 have further processed the original DEMs to fill in these no-data voids with the method described in Reuter et al. 2007. Where other auxiliary DEMs were not available (greater 60° N), the SRTM30 1km product was used as an auxiliary DEM (USGS, 2006).

The “highest quality SRTM data set” version 4.1 is available from the website of the Consortium for Spatial Information (CGIAR-CSI): <http://www.cgiar-csi.org/data/srtm-90m-digital-elevation-database-v4-1#download> in Geographic (latitude/longitude) projection referenced to WGS84 horizontal datum.

EU-DEM

The Digital Elevation Model over Europe from the GMES RDA project (EU-DEM) is a Digital Surface Model (DSM) representing the first surface as illuminated by the sensors. The EU-DEM dataset is a realisation of the Copernicus programme, managed by the European Commission, DG Enterprise and Industry. It is a hybrid product based on SRTM and ASTER GDEM data fused by a weighted averaging approach and it has been generated as a contiguous dataset divided into 1 degree by 1 degree tiles, corresponding to the SRTM naming convention.

The EU-DEM is a 3D raster dataset with elevations captured at 1 arc second (around 30m)

All three datasets are made available as tiles (5x5° or 1000x1000km) and as single files: EU-DEM in ETRS89-LAEA (EPSG code 3035) at: <http://www.eea.europa.eu/data-and-maps/data/eu-dem#tab-european-data>

Hydrosheds

HydroSHEDS (Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales) provides hydrographic information based on SRTM-3 data. The original SRTM data have been hydrologically conditioned using a sequence of automated procedures. Existing methods of data improvement and newly developed algorithms have been applied, including void-filling, filtering, stream burning, and upscaling techniques. Manual corrections were made where necessary (Lehner et al., 2008).

Hydrosheds provides a void-filled digital elevation model, hydrological conditioned elevation, drainage directions and some other layers on 3sec (around 100m) and 15sec (around 500m) at lat/lon projection. The layers can be downloaded at <http://hydrosheds.cr.usgs.gov>.

Pan-European River and Catchment Database

The Pan-European River and Catchment Database was developed by the Catchment Characterisation and Modelling (CCM) activity of the Joint Research Centre (JRC) (Vogt et al. 2007a). In order to derive high quality river networks and catchment boundaries, the 3 arc-second digital elevation model from the Space Shuttle Radar Topography Mission (SRTM) has been processed. The original one degree tiles have been projected, re-sampled and tessellated into a LAEA projection with a grid-cell resolution of 100m. In order to cover the area north of 60° latitude, which is not covered by SRTM, the processed data has been extended with national DEMs from Norway, Sweden, and Finland at 100m grid-cell resolution and USGS GTOPO30 data at 1 km grid-cell resolution for Iceland and the Russian territory (Vogt et al., 2007b). The CCM database covers the entire European continent, including the Atlantic islands, Iceland and Turkey. It includes a hierarchical set of river segments and catchments, a lake layer and structured hydrological feature codes based. Here the flow direction on 100m resolution at LAEA ETRS89 projection are used which can be downloaded at <http://ccm.jrc.ec.europa.eu/php/index.php?action=view&id=23>

4.2 Methodology DEM

Digital elevation model (DEM)

The whole data set is used as base maps at 1km and 5km spatial resolution. Inside LISFLOOD the DEM and its derivate (e.g. standards deviation, slope) were used as variables for the snow processes and for the routing of surface runoff. The DEM is not used for calculation inundation depth. Therefore we avoid the discussion which DEM is the “best” (e.g. SRTM V4 vs. Aster GDEM). For the next update we will use the EU-DEM at 30m resolution, but for this run the EU-DEM came out too late.

In a first step the SRTM V4 was projected to LAEA ETRS89 with the bilinear resampling technique. This technique calculates the new value of a cell based on a weighted distance average of the four nearest input cell centers. It will cause some smoothing of the data.

In a second step the DEM was resampled to 1km and 5km:

The 100m DEM is partitioned into 10x10 and 50x50 cell sized blocks corresponding to the 1km and 5km output resolution. For each of the blocks the minimum, maximum, mean, median and standard deviation is calculated. Table x shows the resulting grids. The average (mean) value certainly smoothen the values of the original 100m grid (see Table 4-1).

Table 4-1: Source 100m DEM and generated target grids

Original DEM 100	Resampled DEM 1km and DEM 5km
100m resolution DEM LAEA ETRS89	Minimum value [m]
	Mean value [m]
	Median value [m]
	Maximum Value [m]
	Standard deviation [m]

Table 4-2: Comparison of values of the source and the resampled DEMs

[m]	DEM100	DEM 1km_mean	DEM 5km_mean
Numbers col. / rows	50000/47500	5000/4750	1000/950
Minimum	-464	-419	-416
Mean	391	388	383
Maximum	5607	5443	4449
Std. deviation	463	461	455

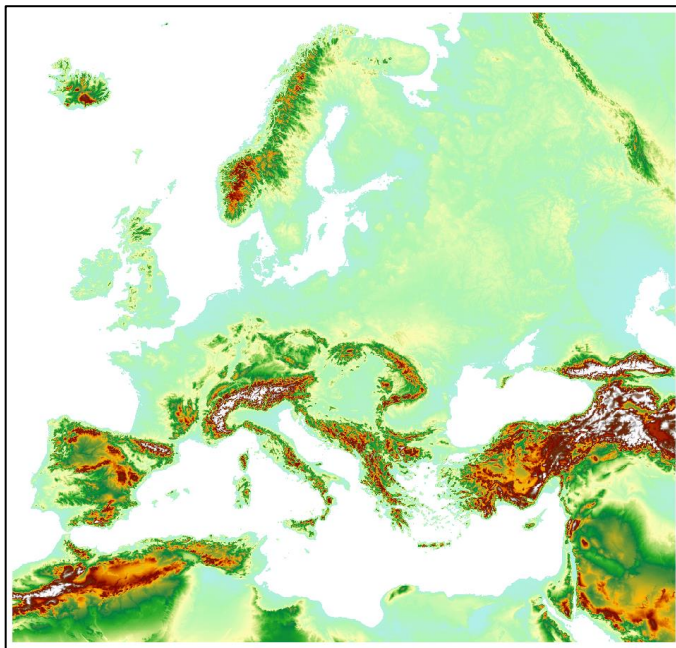


Figure 4-1: Mean digital elevation at 5km resolution

Slope

Slope is defined as the maximum rate of change in value from that cell to its neighbors. The maximum change in elevation between the cell and its eight neighbors identifies the steepest downhill descent from the cell. Slope is then calculated as the steepest downhill decent (rise) compared to the horizontal base (run). The output slope raster can be calculated in two unit, degrees or percent rise. Here the slope is given as ratio between rise and run (Figure 4-2), which can be used directly in LISFLOOD. To get the percent of rise this value has to

multiplied by 100. The inverse tangent (atan) of this value will create the result in degree.

$$\frac{\text{rise}}{\text{run}} = \tan \theta$$

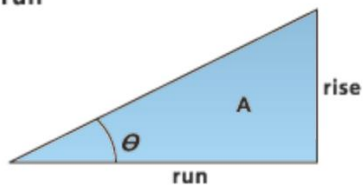


Figure 4-2: Slope as: $\tan \theta = \text{maximum change in elevation} / \text{the distance between the cell}$

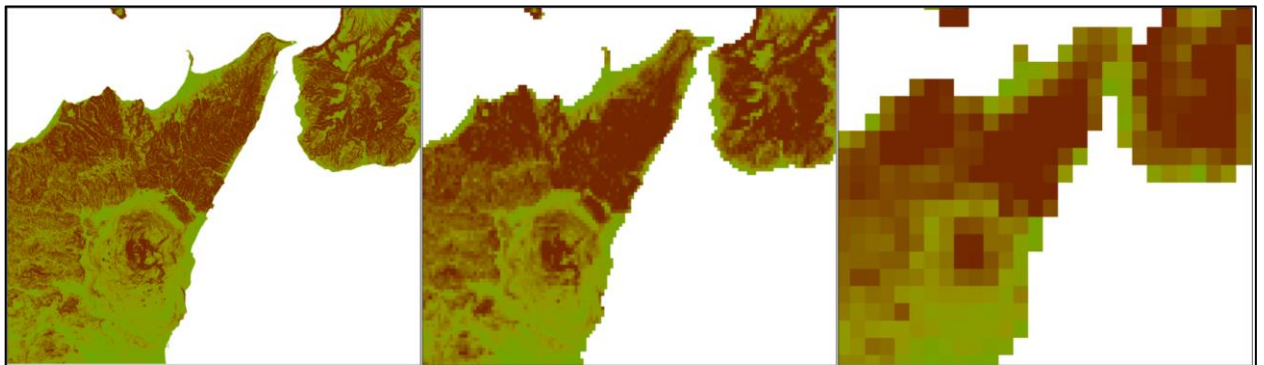


Figure 4-3: Slope (gradient map) as a derivative of SRTM V4 at 100m, 1km and 5km resolution

4.3 Methodology river network

Local drain direction

The local drain direction (LDD) is the essential component to connect the grid cells in order to express the flow direction from one cell to another and forming a river network from the springs to the mouth.

The approach to find the flow direction is in theory quite simple:

There are eight valid output directions relating to the eight adjacent cells into which flow could travel. This approach is commonly referred to as an eight-direction (D8) flow model. The direction from each cell to its steepest downslope neighbour is chosen as flow direction. If the flow direction for each cell is given, a raster of accumulated flow into each cell can be calculated. Figure 4-4 shows the steps from DEM to flow direction to flow accumulation. Flow direction is shown in PCRaster coding of the direction (ArcGIS uses another coding).

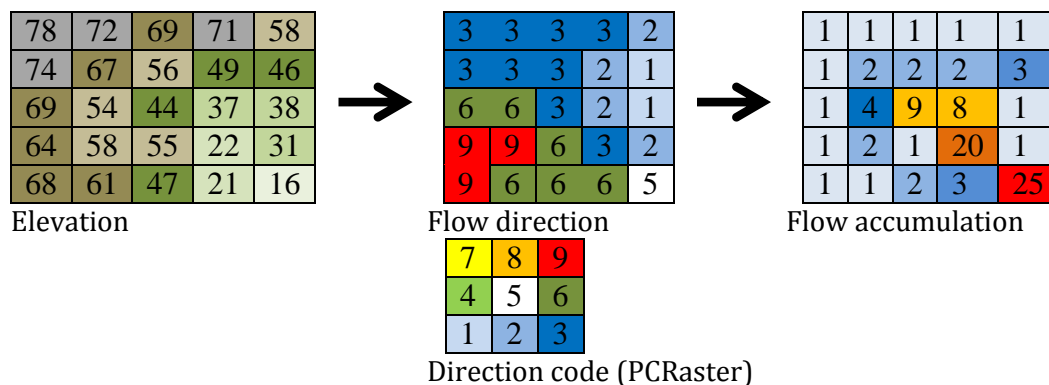


Figure 4-4: From elevation to flow accumulation

Practically it is not as simple because of:

1. The original DEM contains regions of no-data specifically of large water bodies, in mountainous areas, over certain land-surface like bare rocks or sand.
2. Radar-derived products like the SRTM are mostly likely digital surface models but not digital terrain models. A surface model is influenced by the vegetation cover or buildings. In areas of low relief, forest as land cover or urban infrastructure can lead to significant differences compared to a terrain model.
3. An original DEM will show a large number of sinks or depressions. These are single or multiple pixels which are surrounded by higher elevation pixels. Some of these sinks are naturally occurring on the landscape, representing endorheic basins with no outlet to the ocean. In most cases, however, the sinks are considered spurious and caused by deviations in the elevation surface for the reasons mentioned at 1.) and 2.)
4. Due to natural conditions but mostly due to anthropogenic replacements some rivers are on a higher level than the surrounding landscape (see Figure 4-5).



Figure 4-5: Land lower than the river

To overcome these problems, several approaches are used. For example void filling and hydrological conditioning used by Hydrosheds (Lehner et al. 2008). Stream burning method used by Hiederer and de Roo, 2003 and Vogt et al. 2007.)

Stream burning

We have three different datasets (Hydrosheds, SRTM V4, CCM). Unfortunately each of these datasets has its own drawbacks:

1. Hydrosheds is using an older version of SRTM and projecting to LAEA ETRS from WGS harms the conditional hydrological elevation model (because of smoothing) and the river network (because of equivocality of the grid points after projection).
2. SRTM V4 is not a hydrological conditioned elevation model and all the sophisticated methods of e.g. Hydrosheds or CCM have to be applied first.
3. CCM is already in the right projection (LAEA ETRS1989) but uses an older version of the SRTM and does not fit completely to our map extent e.g. North Africa is missing and some coastal areas are not fully included.

Therefore a patchwork of different data and methods is used:

For central Europe the SRTM V4 is filled with the approach of Tarboton et al. 1991 to produce a hydrological sound DEM. But into this DEM the network of CCM is stream burned in for flow accumulations bigger than 1km². By doing so we get the newest SRTM V4 in, especially in mountainous regions and we get also our mask map covered. Figure 4-6 shows as an example the 100m resolution SRTM V4 and the river network from CCM (in blue). You can clearly see that the river from CCM is not always following the lowest elevation. Figure 4-7 shows the resulting river network after “stream burning” with the main river following the “suggestion” of the CCM.

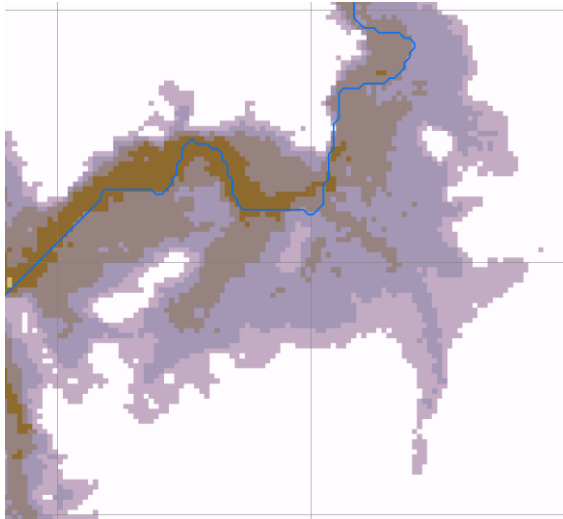


Figure 4-6: Four 5x5km grid cells with 100m SRTM V4 DEM and river network from CCM

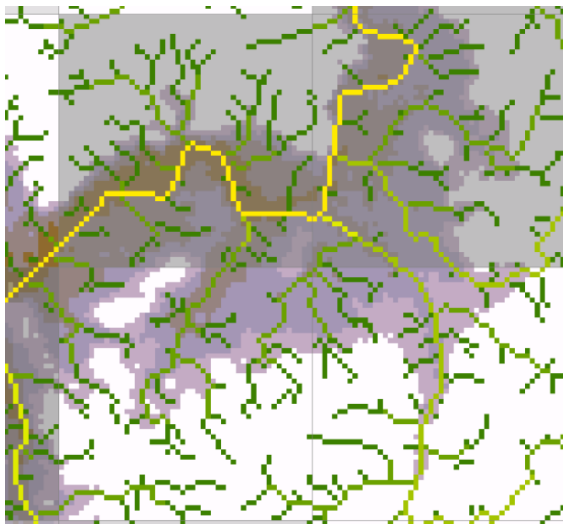


Figure 4-7: River network on 100m resolution from 100m SRTM and burned in CCM rivers

For areas outside the map extend of CCM we use the same approach but we use the information of the Hydrosheds flow accumulation grid for the stream burn method. The result is a 100m resolution pan-European map of flow direction and flow accumulation (basin area at each grid cell)

4.4 Methodology upscaling the river network

Based on the 100m fine resolution river network a method is need to convert the information into 1km and 5km resolution. The procedure of converting fine resolution into coarse-resolution is referred to as an “upscaling method” and various upscaling methods have been proposed to derive river network maps for use in macro-scale river routing models.

For showing different methods the schematic river network from Fekete et al. 2001 is used (Figure 4-8). The blue lines are the fine resolution network, a coarse network is formed by a 3x3 block.

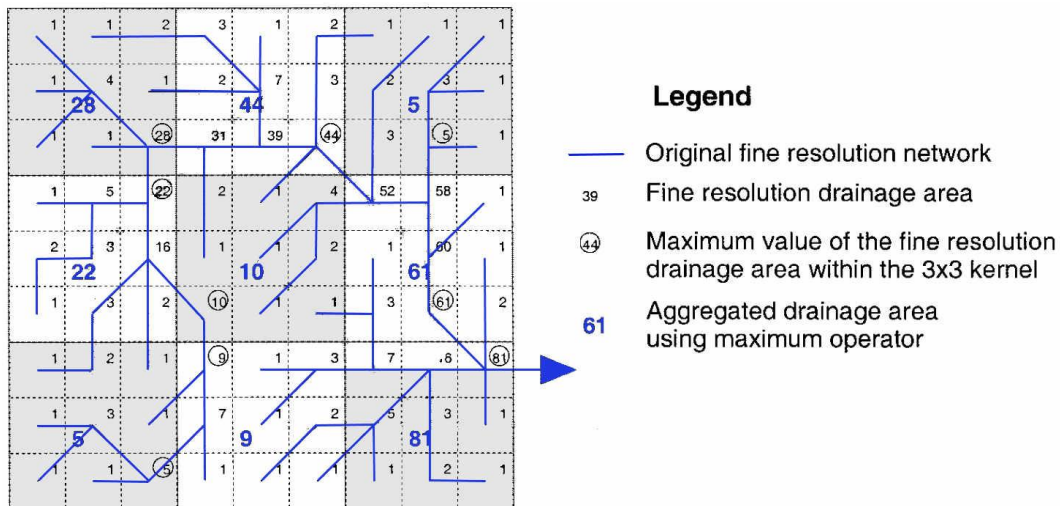


Figure 4-8: Schematic river network, taken as example from Fekete et. al. 2001)

The method of Fekete et al. 2001 and Bodis 2009 first finds the highest flow accumulation for each 3x3 block. The flow direction points of a 3x3 block points to the highest flow accumulation in the neighboring blocks (Figure 4-9)

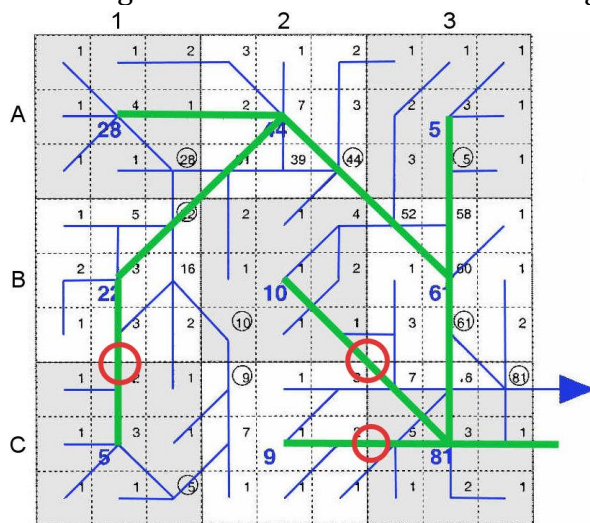


Figure 4-9: Upscaling method of Fekete et al. 2001 and Bodis 2009

The river network used for the pan-European setting of LISFLOOD was done with this method, but with a lot of work put into manual correction.

The main disadvantage of this method:

- Bigger rivers with a higher flow accumulation value catches neighboring blocks to fast. For example Block C3 with a flow accumulation of 81 catches B2 and C2 and B1 catches C1.

The flow direction of the coarser resolution using the method of Döll and Lehner 2001 is defined by the flow direction of the fine resolution cell with the highest flow accumulation within a block.

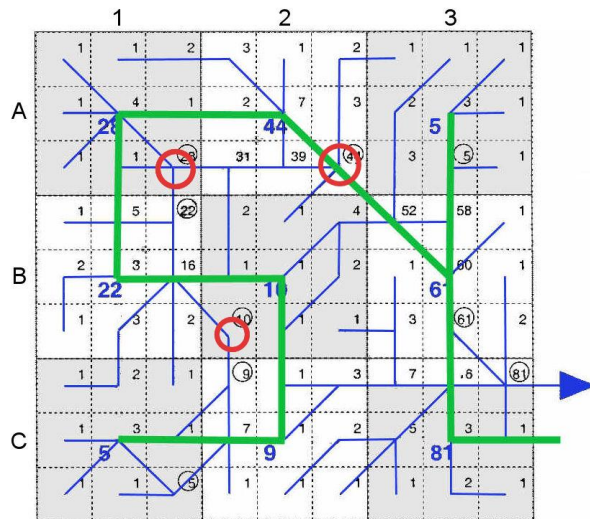


Figure 4-10: Upscaling method of Döll and Lehner 2001

Compared to the river network of Fekete et al. it looks much different. The main disadvantages of this method:

- Low chance that you get a diagonal connection, which gets even lower if you use blocks bigger than 3x3 (see connection A2 – B3 in Figure 4-10 both cells have to be in the corners). Arora and Harrison (2007) address this issue with a modified approach.
- If a bigger river with a high flow accumulation value has only a single pixel in a block and the rest of this block drains to a different direction, this single pixel determines the flow direction (see B2)
-

Another approach is to look at the majority of drain direction inside a block (Figure 4-11). For all the blocks but C2 we get an unambiguous result. But C2 is difficult. Here we have 6 out of nine cells draining east and 3 draining, but with the highest flow accumulation value, draining to the north. Even if you decide that this cell is draining to the east, where is block C1 draining?

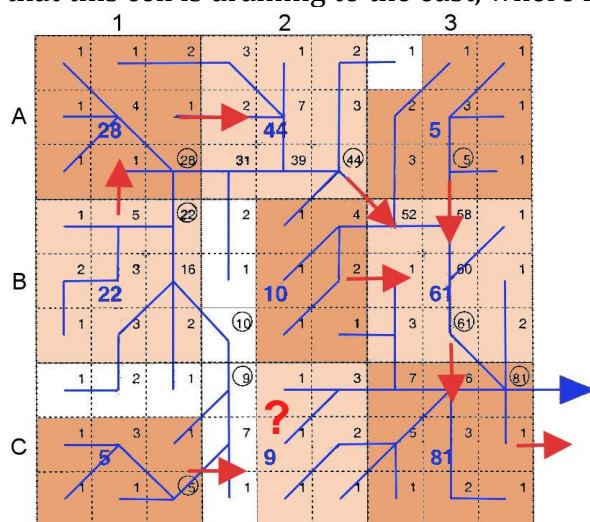


Figure 4-11: Majority of drain direction

Yamazaki et al 2009 and Wu et al. 2011 both use tracing methods to upscale the network. Here we use the method of Yamazaki et al. 2009 called Flexible Location of Waterways (FLOW), because Yamazaki was so kind to share the Fortran code with us. We used this code with some modifications.

The major steps of their work are:

Identifying the outlet point of each block

- The pixel with the largest upstream area inside a block is marked as potential outflow pixel
- The flow path of this potential outflow pixel is traced on the fine resolution grid till the next potential downstream pixel. If the flow path is shorter than a prescribed threshold, the downstream outlet pixel is rejected and the pixel with the second biggest upstream area is tested. This is done till the threshold criterion is fulfilled. The reason for this procedure is to not choose blocks as target cell for the upscaled flow path where the fine flow path just touches this block (see A1 in Figure 4-12).

Construct river network:

- After all potential outflow pixels are validated, the flow path for each outflow pixel to the next outflow pixel downstream is traced and recorded as flow direction of the block
- With this method it is possible that the flow direction is not pointing to one of the eight neighbors but further downstream. For example if two rivers sharing the same block but do not converge. But for LISFLOOD it is necessary that the flow direction points to one of the eight neighbors (D8). Therefore a procedure is use which will find the closest relationship in D8.

Another advantage of tracing methods is that it is possible to derive sub-grid parameters for upscaled river networks like the channel length, flow accumulation, channel slope

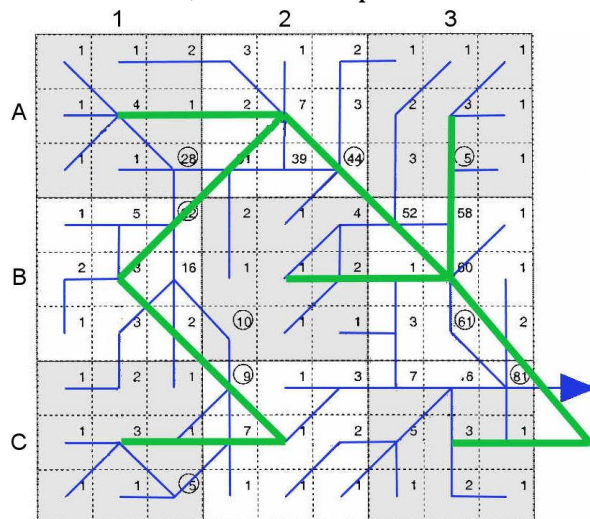


Figure 4-12: Upscaling method of Yamazaki et al. 2009

Figure 4-13 shows three different methods of upscaling (Fekete 2001, Döll and Lehner 2001, Yamazaki 2009). You can see that even for this simple upscaling

problem we get three very different coarse flow networks.

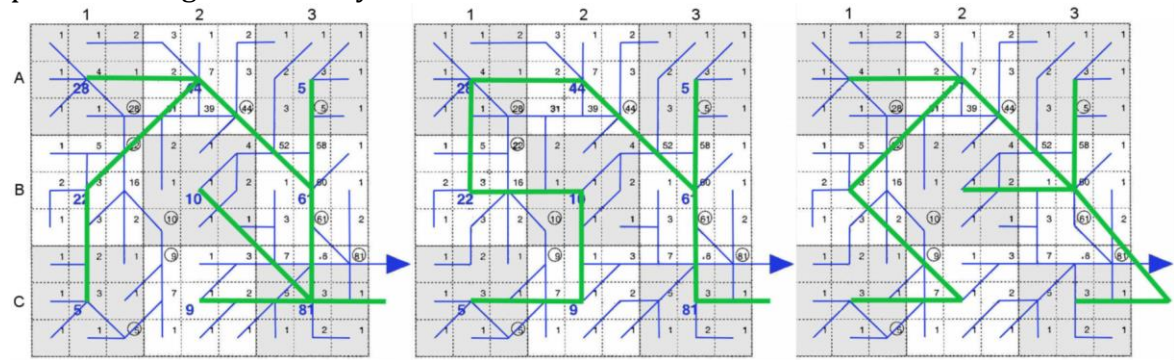


Figure 4-13: Different river network from different upscaling methods

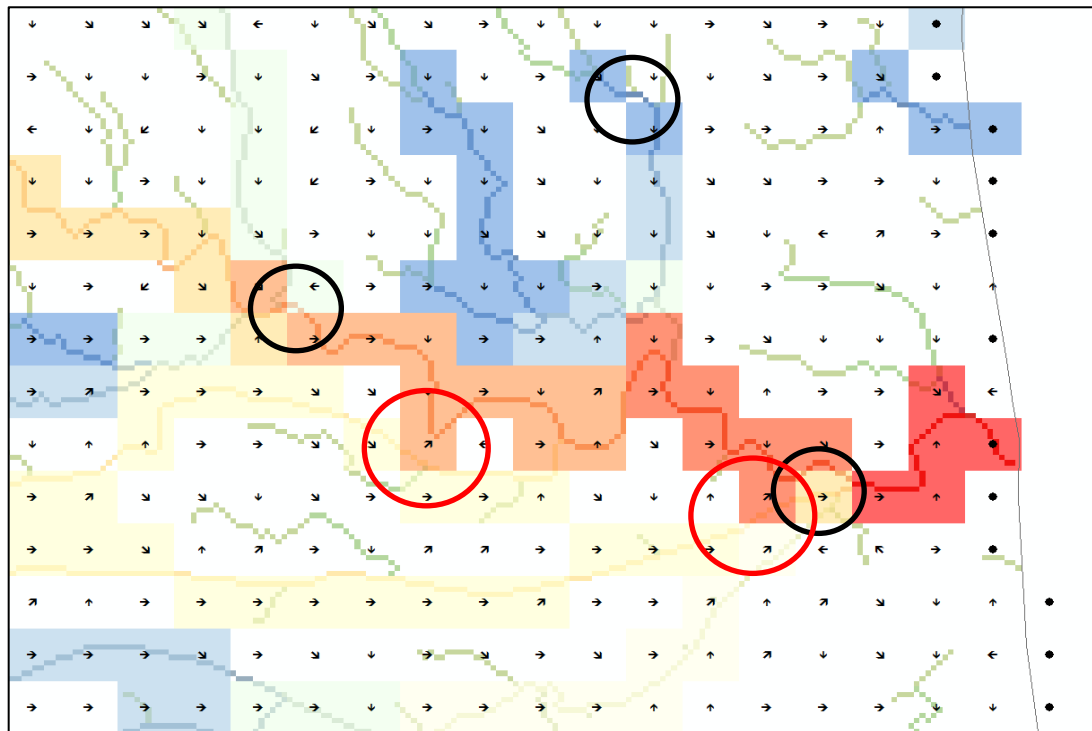


Figure 4-14: River network at 100m and upscaled to 1km East Sicily, river Simeto

Figure 4-14 shows a real example (east Sicily, river Simeto, south of Catania). The black circles mark pixels where the main river only touches the cell in a corner, so this cell is not attached to the main river but to a tributary. The red circles mark cells where there is a conflict between the main river and a tributary. The cell is attached to the main river, but the tributary flow path run also through this cell and is not converging. Therefore the upscaled tributary flow path has to be changed and sometimes this change might be inaccurate.

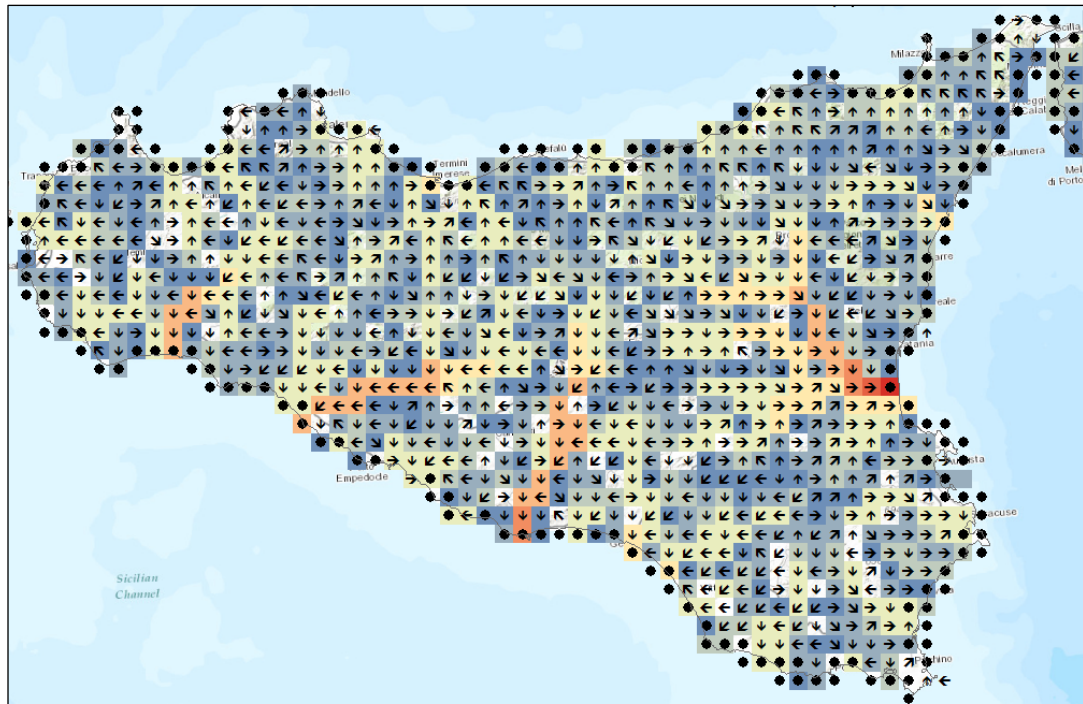


Figure 4-15: 5km Flow network of Sicily at 5km resolution

5 Channel maps

Channel maps are raster maps describing the sub grid information of the channel geometry like the length, slope, width and depth of the main channel inside a grid cell.

5.1 Data

Data are taken from chapter 3 Digital elevation model and channel network mainly the drain direction (LDD), the flow accumulation and the digital elevation model in different resolution.

5.2 Methodology

Flow through the channel is simulated using the kinematic wave equations. The basic equations used are the equations of continuity and momentum.

The continuity equation is:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q$$

where:

- Q : channel discharge [$\text{m}^3 \text{s}^{-1}$],
- A : cross-sectional area of the flow [m^2]
- q : amount of lateral inflow per unit flow length [$\text{m}^2 \text{s}^{-1}$].

The momentum equation can also be expressed as (Chow et al., 1988):

$$A = \alpha \cdot Q^\beta$$

The coefficients α and β are calculated by putting in Manning's equation

$$Q = A \cdot v = \frac{AR^{2/3} \sqrt{S_0}}{n} = \frac{A^{5/3} \sqrt{S_0}}{n P^{2/3}}$$

where:

- v : velocity [m/s]
- n : Manning's roughness coefficient
- P : wetted perimeter of a cross-section of the surface flow [m]
- R : hydraulic Radius $R=A/P$

Solving this for α and β gives (see Burek et al. 2013)

$$\alpha = \left(\frac{n \cdot P^{2/3}}{\sqrt{S_0}} \right)^{0.6} ; \quad \beta = 0.6$$

To calculate α LISFLOOD uses static maps of:

- P : wetted perimeter
approximated in LISFLOOD: $P = \text{channel width} + 2 \cdot \text{channel bankful depth}$
- n : Manning's coefficient
- S_0 : gradient (slope) of the water surface: $S_0 = \Delta \text{elevation} / \text{channel length}$

Channel length

The network upscaling method of Yamazaki et al. 2009 is tracing the finer river network inside the coarser resolution. The river channel length of the coarser resolution is measured along the fine resolution flow path with the diagonal path taken to be $\sqrt{2}$ times of the pixel size (see Figure 5-1 from 1 to 2 and from 2. to 3)

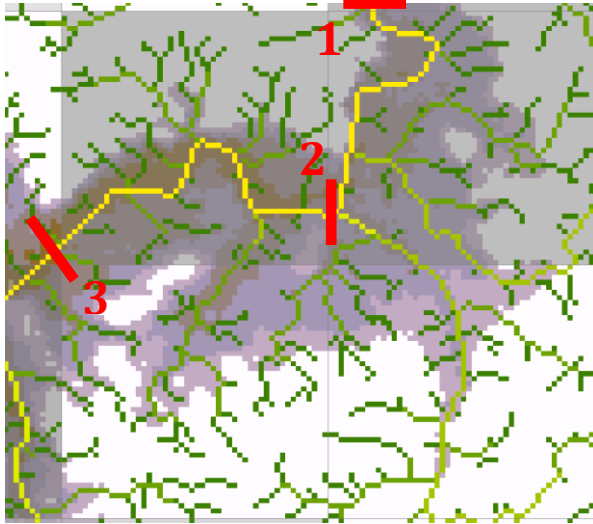


Figure 5-1: Upscaling the river network and calculating the channel length

Channel gradient

Channel gradient (or channel slope) is the average gradient of the main river inside a cell.

One approach is to take the elevation from where the fine resolution channel enters the coarser grid cell and the elevation where it leaves the grid cell (at 1 and at 2 in Figure 5-1). Channel gradient is then calculated as:

$(\text{elevation}[\text{in}] - \text{elevation}[\text{out}]) / \text{channel length}.$

This approach works well, if you use a pure hydrological condition DEM (like Hydroshed's conditional DEM). But we used a "stream burning" and therefore the elevation progression is not straight forward because the river path of the burned river is not always following the lowest elevation. In Figure 5-2 the elevation along the river path for the upper left 5x5km cell and for the upper right 5x5km cell is shown. Calculation the channel slope from only using the first and last 100x100 pixel would lead to misleading slope, especially if the first or last pixel is an outlier.

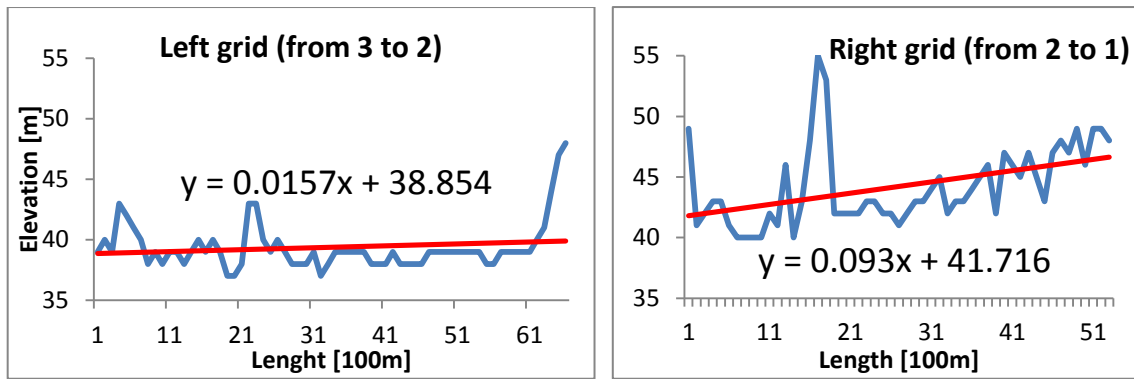


Figure 5-2: Transect of elevation along the burned in 100m river

Here channel gradient is calculated by taking the 10% to 90% quantile of the elevation along the flow path (to sort out outliers) and calculating the inclination.

Absolute median elevation of the channel

The median elevation of a 5x5km channel cell is given by the median elevation along the flow path of the 100x100m pixel flow path (see Figure 5-3)

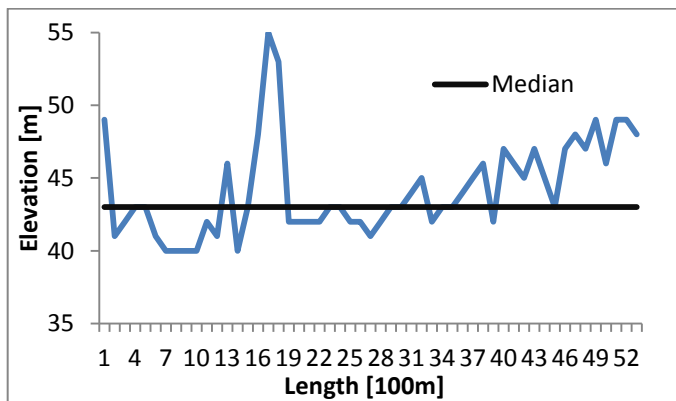


Figure 5-3: Transect of elevation with median elevation.

Channel bottom

Channel bottom level = median elevation of a channel cell – median water level

Where:

- Median elevation: calculated above (Figure 5-3)
- median water level: Median discharge for all cells calculated over a long period and converted into water level using Lisflood option "simulateWaterlevels"

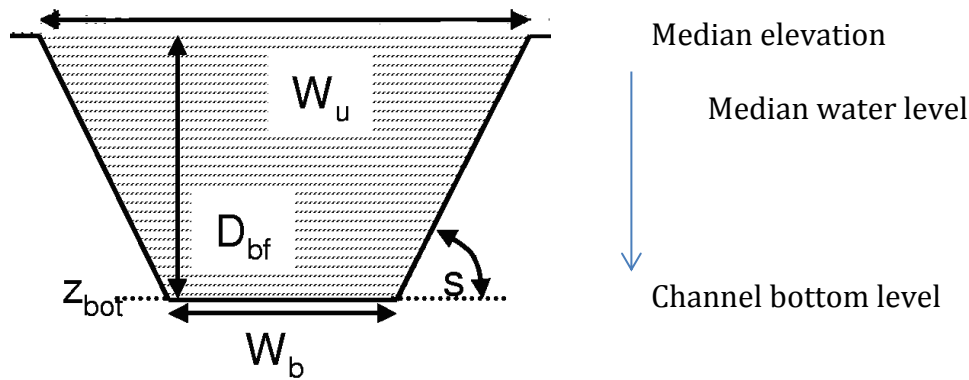


Figure 5-4: Schematic river cross section

The calculation of the channel bottom implies a lot of uncertainty. On the one hand because of the calculation of the median elevation of a channel cell but mainly because of the high uncertainty in calculating the median water level. Using the kinematic wave approach of LISFLOOD gives only a rough approximation about the median water level. To calculate a reasonable robust water level you need an approach using the dynamic wave (solving the St. Venant equation) or at least the diffusion wave. Furthermore the calculation of water levels requires detailed information about channel cross sections.

Manning's roughness

Manning's roughness coefficient (n) is one of the calibration parameter in LISFLOOD. But on subbasin level an estimation of the spatial distribution of n is needed. n normally range between 0.025 (low land rivers) and 0.075 (mountainous rivers with a lot of vegetation, gravels). A low n = smooth surface results in a faster travel time and higher peaks. A high n = rough surface results in a slower travel time and lower peaks. Inspection of the riverbed will reveal characteristics related to roughness. A treatment of the use of Manning's coefficients is in McCuen (1998). Below is a first-approximation of Manning's coefficients for some widely observed beds:

$n = 0.04 - 0.05$	Mountain streams
$n = 0.035$	Winding, weedy streams
$n = 0.028 - 0.035$	Major streams with widths > 30m at flood stage
$n = 0.015$	Clean, earthen channels

For the base map of Manning a regression function is used with 0.025 as the minimum value for flatland rivers with large upstream areas. A maximum of 0.015 is added for flatland rivers and small upstream areas (upstream area dependent) and another maximum of 0.030 is added if in mountainous areas (elevation dependent):

$$\text{Manning} = 0.025 + 0.015 * \min(50/\text{upstream}, 1) + 0.030 * \min(\text{DEM}/2000, 1)$$

Where:

upstream:	upstream catchment area [km]
DEM:	elevation from Digital elevation model [m]

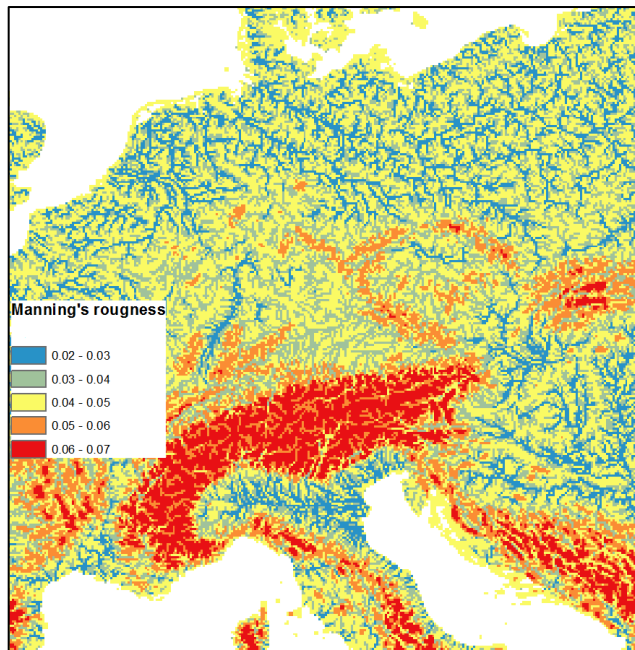


Figure 5-5: Manning's roughness coefficient

Channel Bottom Width

The channel bottom width is calculated in two steps with the first step using a simple regression between channel width and upstream area and the second uses a better correlated one between average discharge and channel width. First the channel bottom width is calculated by a simple regression between upstream catchment area and width:

$$\text{Channel width} = \text{upstreamArea} \times 0.0032$$

This first map is used to run LISFLOOD to get an estimate on average discharge.

In the second step a regression formula from Pistocchi et al. 2006 is used to calculate the channel bottom width with average discharge as regressor, because discharge seems to be better correlated to width than upstream area. This is quite obvious if you look at small alpine catchment with high precipitation and therefore high discharge and on the other side at big, almost semiarid catchments on the Iberian peninsula with low average discharge.

$$\text{Channel width} = \text{average } Q^{0.539}$$

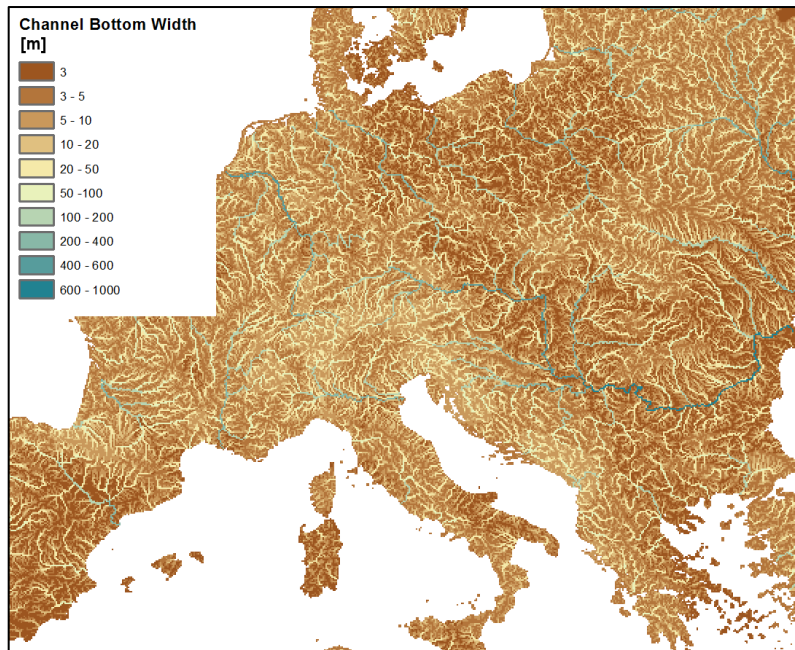


Figure 5-6: Channel bottom width

Channel bankful depth

Instead of deriving channel hydraulic properties from a non linear correlation with the upstream area we are using the Manning's equation to get a better estimate. But for the first estimate (same as for channel bottom width) we use a correlation with upstream area:

$$\text{Channel bankful depth} = 0.27 \text{ upstreamArea}^{0.33}$$

In the second step we use the Manning's equation. We adopt a rectangular cross section and we assume depth is small compared to width. So the perimeter is assumed to be: $P = 1.01 * \text{channel bottom width}$

Discharge for bankful discharge is assumed to be: $Q = 2 * \text{average } Q$

$$Q = \frac{A^{5/3} \sqrt{S_0}}{n P^{2/3}} \approx \frac{(Wh)^{5/3} \sqrt{S_0}}{n (1.01W)^{2/3}}$$

Where:

W: Channel width

h: bankful depth

Q: bankful discharge $\sim 2 * \text{average discharge}$

As we now know all the other variables we can solve this equation for bankful depth with some assumption:

This leads to the equation:

$$\text{Channel bankful depth } (h) = 1.004 \cdot n^{3/5} Q^{3/5} W^{-3/5} S_0^{-3/10}$$

Where:

W: Channel width

Q: bankful discharge $\sim 2 * \text{average discharge}$

6 Soil

6.1 Data source

European Soil Database

A source of uniform data on characteristics of European soils is available from the European Soil Database (ESDB) of the European Soil Bureau (http://eusoils.jrc.ec.europa.eu/esdb_archive/ESDB/Index.htm).

The soil information of the ESDB was collected by participating national institutions and underwent an extensive process of harmonizing the thematic content of recording the soil characteristics and ensuring spatial continuity along boundaries. For the spatial representation of the soil units a vector format is used with characteristics stored in tables in a database format. The conversion of the spatial representation from the vector to a raster format can be readily performed.

Harmonized World Soil Database

The Harmonized World Soil Database 1.2 (HWSD) - Version 1.2 7 March, 2012 was developed by the Land Use Change and Agriculture Program of IIASA (LUC) and the Food and Agriculture Organization of the United Nations (FAO). The HWSD is a 30 arc-second raster database with over 16000 different soil mapping units that combines existing regional and national updates of soil information worldwide – the European Soil Database (ESDB), the 1:1 million soil map of China, various regional SOTER databases (SOTWIS Database), and the Soil Map of the World – with the information contained within the 1:5000000 scale FAO-UNESCO Soil Map of the World. The resulting raster database is linked to harmonized soil property data (FAO et al., 2012)

Hydraulic properties of European soils

To use the soil data of ESDB and HWSD for hydrological models the soil data (types, textures) has to be translated into representative soil hydraulic properties. Therefore the HYPRES project was initiated to bring together the available hydraulic data on soils, residing within different institutions in Europe, into one central database. This information has been used to derive a set of pedotransfer functions (Wösten et al. 1999).

The HYPRES database contains information on a total of 5521 soil horizons. Each soil horizon was allocated to one of 11 possible soil textural/pedological classes derived from the 6 FAO texture classes (5 mineral and 1 organic) and the two pedological classes (topsoil and subsoil) recognised within the 1:1,000,000 scale Soil Geographical Database of Eurasia. The primary use of the data is to derive class pedotransfer functions for topsoils and subsoils based on the five soil texture classes (plus organic soils) currently used to describe the soil units depicted on the 1: 1 000 000 Soil Map of Europe.

6.2 Soil map layers

The ESDB consists of a compilation of several integrated databases, each addressing very different aspects of soil properties. The main attribute databases used for mapping soil properties is the *Soil Geographical Database of Europe* (SGDBE).

The SGDBE consists of several components: a spatial component given by a digitized soil map (SGDBE_4) as vector map containing the *Spatial Mapping Units* (SMU), non-spatial tables of related attributes Soil Typological Units (STU) and information on linking soil attributes to the spatial units (STU_ORG). A SMU can be linked to several STUs. Hiederer 2013 describes the SGDBE in detail and also the procedure to obtain 1km resolution single layer of dominant STU maps.

The soil data of the European Soil Database Version 2.0 does not cover the whole map extent. For these regions the data were taken from the Harmonized World Soil Database (Hiederer 2011).

Soil texture

Soil texture refers to the proportion of sand, silt and clay of mineral soils. The smallest particles are *clay* particles as having diameters of less than 0.002 mm. The next smallest particles are *silt* particles and have diameters between 0.002 and 0.063 mm. The largest particles are *sand* particles and are larger than 0.063 mm in diameter. The soil texture was derived on topsoil (Figure 6-1) and subsoil levels with the condition that the sum of the three components is 100%. For the areas covered by the ESDB the topsoil texture classes are defined by the dominant soil typological unit of a mapping unit. For areas outside the ESDB the texture classes were generated from the HWSD

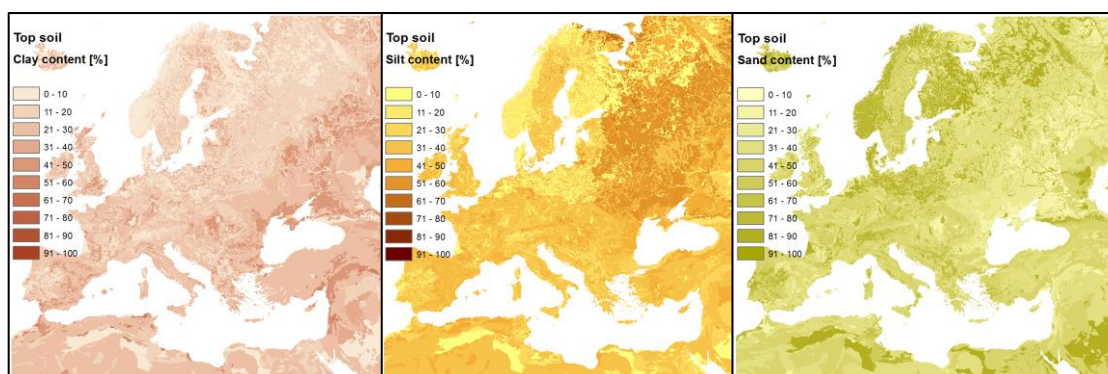


Figure 6-1: Soil texture as percentage of clay, silt, sand at 1km resolution

Bulk density

The soil bulk or dry density is the ratio of the mass of the solid phase of the soil (i.e., dried soil) to its total volume (solid and pore volumes together). The dry density of most soils varies within the range of 1.1-1.6 g/cm³. In sandy soils, dry density can be as high as 1.6 g/cm³; in clayed soils and aggregated loams, it can be as low as 1.1 g/cm³ and a high percentage of organic matter can reduce it up to 0.3 g/cm³.

Organic matter

The source data of the topsoil organic carbon map (European Soil Database Version 2.0) does not cover soil data for the whole map extent. For these regions the data were taken from the Harmonized World Soil Database (Hiederer 2011). Organic matter which is used as parameter inside the pedotransfer function of HYPRES has to be calculated from the map of topsoil organic carbon by applying a factor of 1.72. This factor assumes an average organic carbon content of organic matter of 58%.

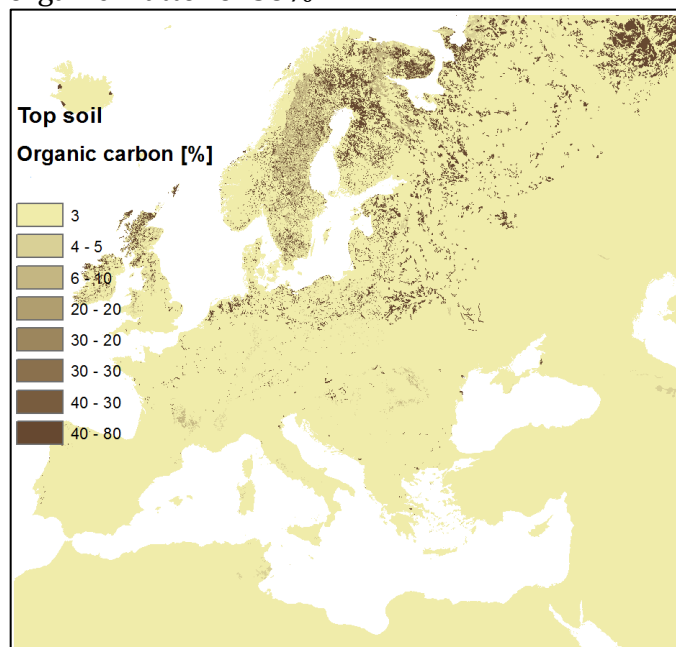


Figure 6-2: Organic carbon

Soil depth

Soil depth is taken from the ESDB database (Attribute ROO: Depth class of an obstacle to roots within the STU) and from the HWSD (Attribute Ref depth: An approximation of actual soil depth derived through accounting for relevant depth limiting soil phases, obstacles to roots and occurrence of impermeable layers)

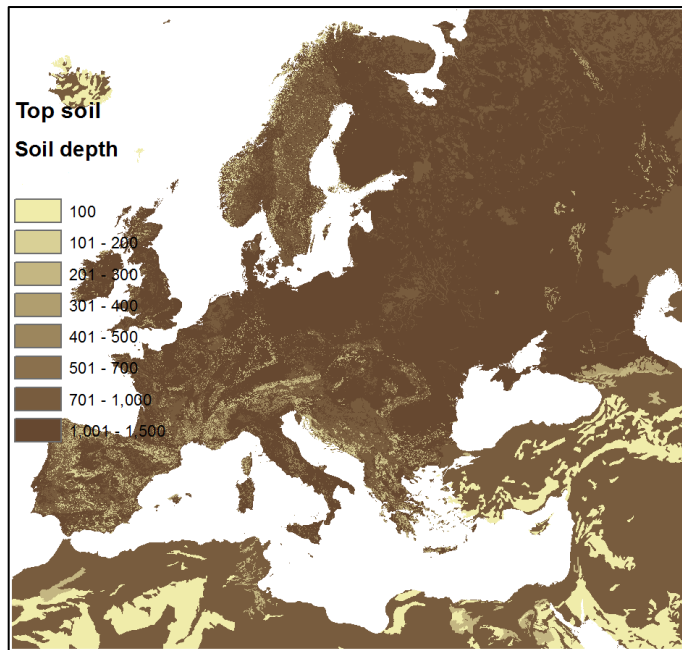


Figure 6-3: Soil depth at 1km resolution

6.3 Methodology

Continuous pedotransfer functions for the prediction of hydraulic properties

The soil layers clay percentage, sand percentage, bulk density and organic carbon are used to calculate the hydraulic properties using the pedotransfer function from the HYdraulic PROPERTIES of European Soils (HYPRES) Wösten et al. 1999 and <http://eussoils.jrc.ec.europa.eu/>.

A map set of hydraulic properties contains a top- and a sub soil set of saturated and residual volumetric soil moisture (θ_s , θ_R), pore size index (λ), saturated conductivity (K_s) and van Genuchten parameter α .

$$\theta_s = 0.7919 + 0.001691*C - 0.29619*D - 0.000001491*S^2 + 0.0000821*OM^2 + 0.02427*C^{-1} + 0.01113*S^{-1} + 0.01472*\ln(S) - 0.0000733*OM*C - 0.000619*D*C - 0.001183*D*OM - 0.0001664*topsoil*S$$

$$K_s = 7.755 + 0.0352*S + 0.93*topsoil - 0.967*D^2 - 0.000484*C^2 - 0.000322*S^2 + 0.001*S^{-1} - 0.0748*OM^{-1} - 0.643*\ln(S) - 0.01398*D*C - 0.1673*D*OM + 0.02986*topsoil*C - 0.03305*topsoil*S$$

$$\alpha^* = -14.96 + 0.03135*C + 0.0351*S + 0.646*OM + 15.29*D - 0.192*topsoil - 4.671*D^2 - 0.000781*C^2 - 0.00687*OM^2 + 0.0449*OM^{-1} + 0.0663*\ln(S) + 0.1482*\ln(OM) - 0.04546*D*S - 0.4852*D*OM + 0.00673*topsoil*C$$

$$n^* = -25.23 - 0.02195*C + 0.0074*S - 0.1940*OM + 45.5*D - 7.24*D^2 + 0.0003658*C^2 + 0.002885*OM^2 - 12.81*D^{-1} - 0.1524*S^{-1} - 0.01958*OM^{-1} - 0.2876*\ln(S) - 0.0709*\ln(OM) - 44.6*\ln(D) - 0.02264*D*C + 0.0896*D*OM + 0.00718*topsoil*C$$

Where:

θ_s : saturated volumetric soil moisture

K_s : Saturated conductivity

α : Van Genuchten parameter: $\exp(\alpha^*)$

n^* : Pore size index (λ) = $n-1 = \exp(n^*)-1$

C,S: percentage clay, percentage sand

OM: percentage organic matter (=1.72 x organic carbon),

D: bulk density

topsoil and subsoil: qualitative variables having the value of 1 or 0

Residual volumetric soil moisture is calculated as:

$$\theta_R = (0.2*C + 0.1*S + 0.05*(100 - C - S))/100$$

Organic carbon is multiplied by 1.72 to get organic matter (Hiederer 2011).

LISFLOOD needs a map set for forest and non forest. The distinction between forest and non-forest soil properties is done by assuming a higher organic matter and lesser bulk density for the first layer of soil in forested areas. The influence of land use change on soil organic matter and bulk density has been studied, and relative changes in both parameters for different land use transitions can be estimated from literature (Burek et al., 2012, Bormann et al., 2007; Laganiere et al., 2010).

For the calculation of the soil properties the organic carbon and bulk density is changed according to the percentage of forest in the 1km resolution maps.

For forest it is assumed that for each percent of forest the organic carbon will increase by 0.1% and the bulk density will decrease by 0.1% e.g. for a cell with

60% forest the organic carbon will be multiplied by 1.06 and the bulk density by 0.94. These new values will be then put into the equations above. For non-forested areas forest it is assumed that for each percent of forest the organic carbon will decrease by 0.1% and the bulk density will increase by 0.1% e.g. for a cell with 60% forest the organic carbon will be multiplied by 0.94 and the bulk density by 1.06.

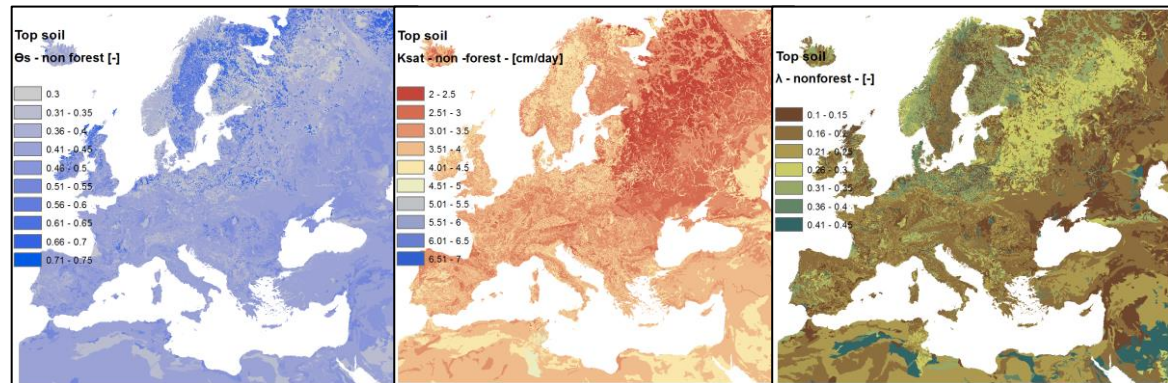


Figure 6-4: Saturated soil moisture, saturated conductivity and pore size index

Soil depth

Lisflood is using two soil layers (topsoil, subsoil) to model the hydrological processes in the soil. Texture, bulk density, organic matter maps already come as top- and subsoil maps, but the soil depth has to be split in to two layers and also in a forest and non forest map.

Non forest maps:

To calculate the root depth, a lookup table from Laguardia, 2005 (see Annex 3) is used based on the Corine land cover classes.

To calculate the soil depth of the topsoil following rules are applied:

- Minimum of either the root depth or the total soil depth minus 300mm
- The top soil depth is minimum 50mm
- If the total soil depth is less than 300mm, top- and sub soil depth is half of total soil depth
- sub soil depth = total soil depth – top soil depth

For the 5km resolution the 1km map is resampled by calculating the average in each 5km cell.

Forest maps:

Same procedure as for the non forest maps but a root depth of 1500mm is assumed instead of using the lookup table.

7 Leaf area index

The Leaf Area Index (LAI) in m^2 of leaf area on 1m^2 reflects the foliage density per ground surface, and plays an important role in the interception of water and evapotranspiration. Leaf area is not a static map but a value which evolves during the year. The development of vegetation over time is accounted for in the model by a stack of 36 LAI maps.

The LAI products derived from SPOT-VGT data, (CYCLOPES and VITO), are globally reprocessed to provide a spatiotemporally continuous time series (as ten day composites) in spatial resolution of 1 km.

The data is available as 36 global ten-day composites for LAI for each year of the period 1999-2007 and the year 2010 and can be retrieved by the WDC/DLR website (http://wdc.dlr.de/data_products/SURFACE/LAI).

7.1 Methodology

Calculating a reference year

In a first step the images from 1999-2003 were shifted to fit to the images from 2004-2007 and 2010. Then a LAI reference year was calculated by taking the average of all 10 years for each of the 36 maps.

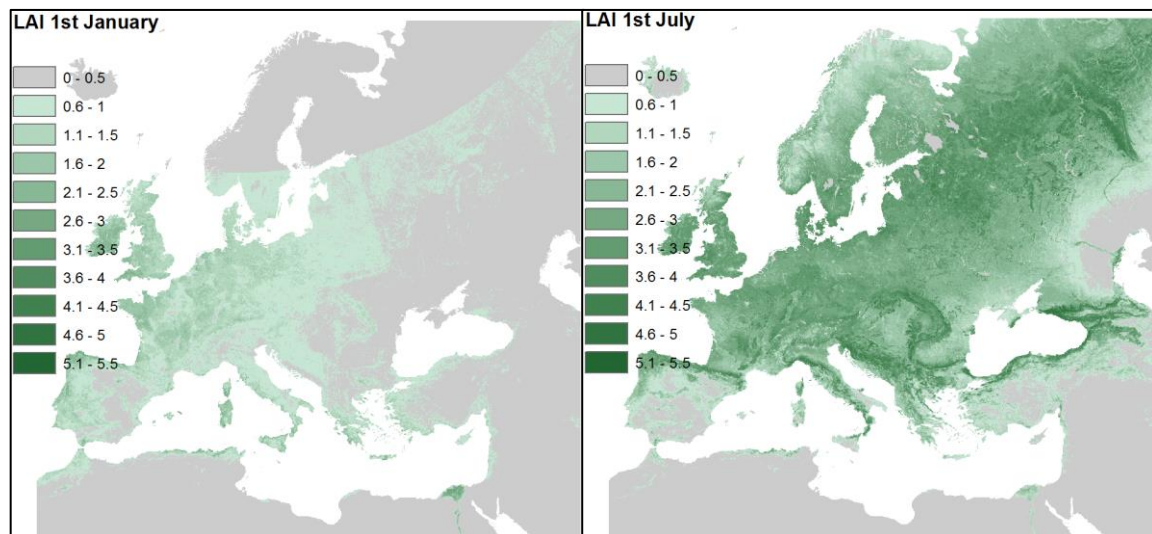


Figure 7-1: Leaf Area Index for January and for July

Split into forest and non-forest

For LISFLOOD a map set is needed for calculating forest soils and another map set is needed to calculate the non-forest percentage of a cell (also see LISFLOOD user manual Burek et al. 2013 p.9ff).

Therefore the percentage of forest coverage (see chapter 3.2) is used. Every pixel on 1km resolution with a forest coverage of more or equal 70% is selected as

interpolation point for the forest LAI maps and every point less or equal 20% forest coverage is selected for the non-forest LAI.

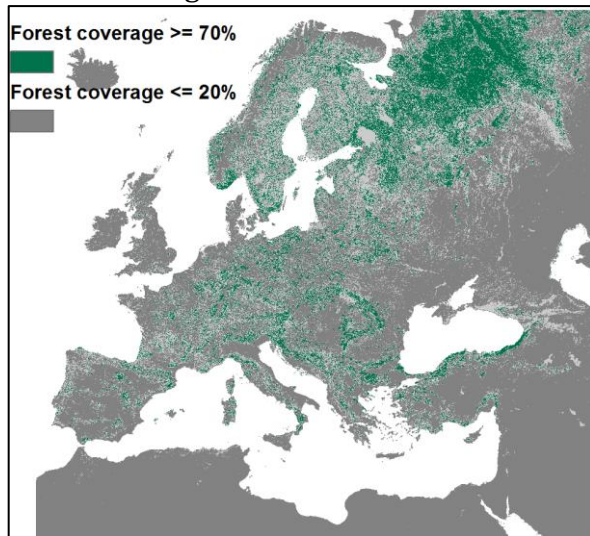


Figure 7-2: Overlay of two boolean maps: Forest coverage $\geq 70\%$ and $\leq 20\%$

These interpolation points are used for an inverse distance interpolation for all 36 maps of the LAI map stack. In detail:

- The interpolation points (e.g. all green points in Figure 7-2) get the value of a single LAI map (e.g. the map of 1st January)
- The points with the value of 1st January are now interpolated to all the valid pixels of the mask map.

The same is done for the non-forest points using the $\leq 20\%$ map as reference. This results in two map stacks of 36 single maps, one for forest and one for non-forest see (Figure 7-3 for an example 1st July).

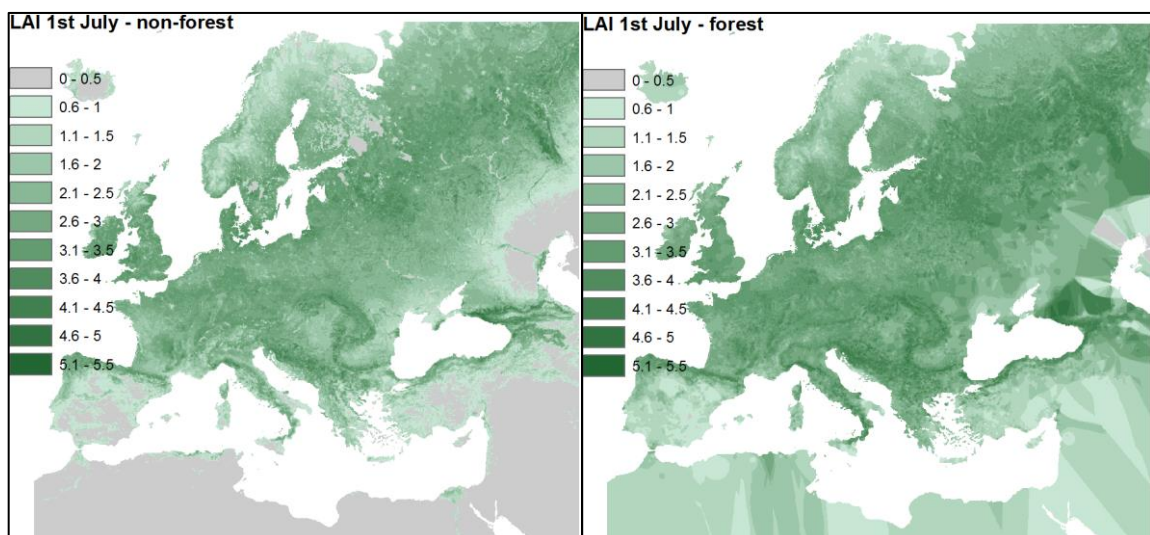


Figure 7-3: LAI for forest and non-forest at 5km resolution

8 Summary and conclusions

This technical report describes the static input layers for the LISFLOOD model. The data set contains gridded numerical information related to topography, channel geometry, land cover and soil characteristics at a pan-European scale. It is an updated version of the technical report “Development of a data set for continental hydrologic modelling” of Katalin Bódis.

An update was necessary because:

- The projection changed from LAEA GISCO to Inspire conform LAEA ETRS89
- The maps now include Turkey and the northern part of Africa
- Data source was renewed e.g.
 - o refined version of Corine 2006 for land cover
 - o newer version of processed SRTM
 - o updated version of Soil Database of Eurasia and World Harmonised Soil Database
 - o Leaf Area Index from SPOT-VGT data
- The methodology was changed e.g.
 - o Upscaling the river network,
 - o Creating channel maps (channel length, channel gradient etc.)
 - o Using maps (e.g. crop coefficient) which are based on fine resolution (e.g. land cover 100m resolution) and then upscaled to 5km instead of lookup tables which are used with the dominant land cover of 5km.

9 Acknowledgements

I would like to acknowledge all the GIS experts, namely Alessandra Bianchi, Alessandro Gentile and Marco Trombetti, who helped me to produce the maps. Furthermore, I would like to acknowledge Katalin Bódis for the technical report on the first data set and verbal advice, which was very helpful to write this booklet.

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Annex 1: ETRS-LAEA Description

Entity	Value
CRS ID	ETRS-LAEA
CRS alias	ETRS89 Lambert Azimuthal Equal Area CRS
CRS valid area	Europe
CRS scope	CRS for pan-European statistical mapping at all scales or other purposes where true area representation is required
Datum ID	ETRS89
Datum alias	European Terrestrial Reference System 1989
Datum type	geodetic
Datum realization epoch	1989
Datum valid area	Europe / EUREF
Datum scope	European datum consistent with ITRS at the epoch 1989.0 and fixed to the stable part of the Eurasian continental plate for georeferencing of GIS and geokinematic tasks
Datum remarks	see Boucher, C., Altamimi, Z. (1992): The EUREF Terrestrial Reference System and its First Realizations. Veröffentlichungen der Bayerischen Kommission für die Internationale Erdmessung, Heft 52, München 1992, pp 205-213 - or - ftp://lareg.ensg.ign.fr/pub/euref/info/guidelines
Prime meridian ID	Greenwich
Prime meridian Greenwich longitude	0°
Ellipsoid ID	GRS 80
Ellipsoid alias	New International
Ellipsoid semi-major axis	6 378 137 m
Ellipsoid shape	true
Ellipsoid inverse flattening	298.257222101
Ellipsoid remarks	see Moritz, H. (1988): Geodetic Reference System 1980. Bulletin Geodesique, The Geodesists Handbook, 1988, Internat. Union of Geodesy and Geophysics
Coordinate system ID	LAEA
Coordinate system type	projected
Coordinate system dimension	2
Coordinate system axis name	Y
Coordinate system axis direction	North
Coordinate system axis unit identifier	metre
Coordinate system axis name	X
Coordinate system axis direction	East
Coordinate system axis unit identifier	metre
Operation ID	LAEA
Operation valid area	Europe
Operation scope	for pan-European statistical mapping at all scales or other purposes where true area representation is required
Operation method name	Lambert Azimuthal Equal Area Projection
Operation method formula	US Geological Survey Professional Publication 1395, "Map Projection – A Working Manual" by John P. Snyder.
Operation method parameters number	4
Operation parameter name	latitude of origin
Operation parameter value	52° N
Operation parameter name	longitude of origin
Operation parameter value	10° E
Operation parameter remarks	
Operation parameter name	false northing
Operation parameter value	3 210 000.0 m
Operation parameter remarks	
Operation parameter name	false easting
Operation parameter value	4 321 000.0 m
Operation parameter remarks	

from <http://spatialreference.org/ref/epsg/etrs89-etrs-laea>

Annex 2: Conversion table between GlobCover 2009 and CORINE land cover

Code and land cover type GlobCover 2009		Code and land cover type Corine 2000 & 2006	
11	Post-flooding or irrigated croplands (or aquatic)	13	Permanently irrigated land
14	Rainfed croplands	12	Non-irrigated arable land
20	Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)	12	Non-irrigated arable land
30	Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)	12	Non-irrigated arable land
40	Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (>5m)	25	Mixed forest
50	Closed (>40%) broadleaved deciduous forest (>5m)	23	Broad-leaved forest
60	Open (15-40%) broadleaved deciduous forest/woodland (>5m)	27	Moors and heathland
70	Closed (>40%) needleleaved evergreen forest (>5m)	24	Coniferous forest
90	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)	24	Coniferous forest
100	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)	25	Mixed forest
110	Mosaic forest or shrubland (50-70%) / grassland (20-50%)	27	Moors and heathland
120	Mosaic grassland (50-70%) / forest or shrubland (20-50%)	23	Broad-leaved forest
130	Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m)	29	Transitional woodland-shrub
140	Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses)	18	Pastures
150	Sparse (<15%) vegetation	32	Sparsely vegetated areas
160	Closed to open (>15%) broadleaved forest regularly flooded (semi-permanently or temporarily) - Fresh or brackish water	37	Salt marshes
170	Closed (>40%) broadleaved forest or shrubland permanently flooded - Saline or brackish water	37	Salt marshes
180	Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil - Fresh, brackish or saline water	35	Inland marshes
190	Artificial surfaces and associated areas (Urban areas >50%)	2	Discontinuous urban fabric
200	Bare areas	31	Bare rocks
210	Water bodies	41	Water bodies
220	Permanent snow and ice	34	Glaciers and perpetual snow

Annex 3: Lookup tables based on Corine land cover

Impermeability, Percentage of water coverage

Corine grid code and description	Sealed Area [%]	Water cover. [%]	Root depth [cm]	Manning's coeff [-]	Crop coef. [-]	Crop group no. [-]
1	Continuous urban fabric	0.75	10	0.02	0.9	2
2	Discontinuous urban fabric	0.50	10	0.02	0.9	2
3	Industrial or commercial units	0.75	10	0.02	0.9	2
4	Road and rail networks	0.50	20	0.02	1	2
5	Port areas	0.75	10	0.02	0.9	2
6	Airports	0.50	20	0.01	1	2
7	Mineral extraction sites	0.50	10	0.1	0.9	2
8	Dump sites	0.25	20	0.1	0.9	2
9	Construction sites	0.25	10	0.1	0.9	2
10	Green urban areas	0.25	50	0.1	1.1	2
11	Sport and leisure facilities	0.25	50	0.15	1	2
12	Non-irrigated arable land		100	0.08	1	3.
13	Permanently irrigated land		50	0.08	1.1	2
14	Rice fields		70	0.08	1.2	1
15	Vineyards		150	0.08	0.9	3
16	Fruit trees, berry plantations		100	0.25	1	3
17	Olive groves		150	0.25	0.9	4
18	Pastures		30	0.25	1	3
19	Annual crops		100	0.08	1	3
20	Complex cultivation patterns		50	0.15	1	3
21	Land p. occ. by agriculture		100	0.2	1	3
22	Agro-forestry areas		120	0.15	1	3
23	Broad-leaved forest		150	0.3	1	3
24	Coniferous forest		150	0.3	1	4
25	Mixed forest		150	0.3	1	3.
26	Natural grasslands		30	0.25	1	3
27	Moors and heathland		50	0.2	1	3
28	Sclerophyllous vegetation		50	0.2	1	4
29	Transitional woodland-shrub		50	0.25	1	3
30	Beaches, dunes, sands		50	0.05	1	2
31	Bare rocks	0.75	5	0.1	1	2
32	Sparsely vegetated areas		50	0.08	1	3
33	Burnt areas		50	0.05	1	3
34	Glaciers and perpetual snow	0.75	5	0.1	1	2
35	Inland marshes		50	0.2	1.1	1
36	Peat bogs		50	0.2	1.1	1
37	Salt marshes		100	0.05	1	2
38	Salines		50	0.05	1	2
39	Intertidal flats	-	-	-	-	-
40	Water courses		50	0.015	1	1
41	Water bodies		50	0.015	1	1
42	Coastal lagoons	-	-	-	-	-
43	Estuaries	-	-	-	-	-
44	Sea and ocean	-	-	-	-	-

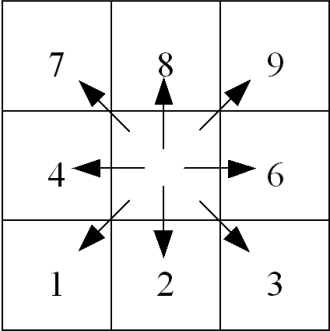
Annex 4: New European input maps for LISFLOOD

The complete list of LISFLOOD input maps is also given in the User Manual (Burek et al. 2013) in Annex 12.

For features like simulating lakes, reservoirs, water use additional maps are needed (see User Manual Annex 1-10):

- Reservoirs, polders, lakes (location map)
- Inflow hydrographs (location map)
- Water use (stack of water use maps)

Table 0-1: Lisflood input maps

GENERAL			
Map	Default name ¹	Units, range	Description
MaskMap	area.map	Unit: - Range: 0 or 1	Boolean map that defines model boundaries
TOPOGRAPHY			
Map	Default name	Units, range	Description
Ldd	ldd.map	U.: flow directions R.: $1 \leq \text{map} \leq 9$	local drain direction map (with value 1-9); this file contains flow directions from each cell to its steepest downslope neighbour. Ldd directions are coded according to the following diagram:  This resembles the numeric key pad of your PC's keyboard, except for the value 5, which defines a cell without local drain direction (pit). The pit cell at the end of the path is the outlet point of a catchment.
Grad	gradient.map	U.: $[m\ m^{-1}]$ R.: $\text{map} > 0$	Slope gradient
Elevation Stdev	elvstd.map	U.: [m] R.: $\text{map} \geq 0$	Standard deviation of elevation

¹ The file names listed in the table are not obligatory. However, it is suggested to stick to the default names suggested in the table. This will make both setting up the model for new catchments as well as upgrading to possible future LISFLOOD versions much easier.

LAND USE - fraction maps			
Map	Default name	Units, range	Description
Fraction of water	fracwater.map	U.: [-] R.: $0 \leq \text{map} \leq 1$	Fraction of inland water for each cell. Values range from 0 (no water at all) to 1 (pixel is 100% water)
Fraction of sealed surface	fracsealed.map	U.: [-] R.: $0 \leq \text{map} \leq 1$	Fraction of impermeable surface for each cell. Values range from 0 (100% permeable surface – no urban at all) to 1 (100% impermeable surface).
Fraction of forest	fracforest.map	U.: [-] R.: $0 \leq \text{map} \leq 1$	Forest fraction for each cell. Values range from 0 (no forest at all) to 1 (pixel is 100% forest)
Fraction of other land cover	fracother.map	U.: [] R.: $0 \leq \text{map} \leq 1$	Other (agricultural areas, non-forested natural area, pervious surface of urban areas) fraction for each cell.
LAND COVER depending maps			
Map	Default name	Units, range	Description
Crop coef. for forest	cropcoef_forest.map	U.: [-] R.: $0.8 \leq \text{map} \leq 1.2$	Crop coefficient for forest
Crop coef. for other	cropcoef_other.map	U.: [-] R.: $0.8 \leq \text{map} \leq 1.2$	Crop coefficient for other
Crop group number for forest	crgnum_forest.map	U.: [-] R.: $1 \leq \text{map} \leq 5$	Crop group number for forest
Crop group number for other	crgnum_other.map	U.: [-] R.: $1 \leq \text{map} \leq 5$	Crop group number for other
Manning for forest	mannings_forest.map	U.: [-] R.: $0.2 \leq \text{map} \leq 0.4$	Manning's roughness for forest
Manning for other	mannings_other.map	U.: [-] R.: $0.01 \leq \text{map} \leq 0.3$	Manning's roughness for other
Soil depth for forest for layer1	soildep1_forest.map	U.: [mm] R.: $\text{map} \geq 50$	Forest soil depth for soil layer 1 (rooting depth)
Soil depth for other for layer2	soildep1_other.map	U.: [mm] R.: $\text{map} \geq 50$	Other soil depth for soil layer 1 (rooting depth)
Soil depth for forest for layer2	soildep2_forest.map	U.: [mm] R.: $\text{map} \geq 50$	Forest soil depth for soil layer 2
Soil depth for other for layer2	soildep2_other.map	U.: [mm] R.: $\text{map} \geq 50$	Other soil depth for soil layer 2

SOIL HYDRAULIC PROPERTIES (depending on soil texture)			
Map	Default name	Units, range	Description
ThetaSat1 for forest	thetas1_forest.map	U.: [-] R.: $0 < \text{map} < 1$	Saturated volumetric soil moisture content layer 1
ThetaSat1 for other	thetas1_other.map	U.: [-] R.: $0 < \text{map} < 1$	Saturated volumetric soil moisture content layer 1
ThetaSat2 for forest and other	thetas2.map	U.: [-] R.: $0 < \text{map} < 1$	Saturated volumetric soil moisture content layer 2
ThetaRes1 for forest	thetar1_forest.map	U.: [-] R.: $0 < \text{map} < 1$	Residual volumetric soil moisture content layer 1
ThetaRes1 for other	thetar1_other.map	U.: [-] R.: $0 < \text{map} < 1$	Residual volumetric soil moisture content layer 1
ThetaRes2 for forest and other	thetar2.map	U.: [-] R.: $0 < \text{map} < 1$	Residual volumetric soil moisture content layer 2
Lambda1 for forest	lambda1_forest.map	U.: [-] R.: $0 < \text{map} < 1$	Pore size index (λ) layer 1
Lambda1 for other	lambda1_other.map	U.: [-] R.: $0 < \text{map} < 1$	Pore size index (λ) layer 1
Lambda2 for forest and other	lambda2.map	U.: [-] R.: $0 < \text{map} < 1$	Pore size index (λ) layer 2
GenuAlpha1 for forest	alpha1_forest.map	U.: [-] R.: $0 < \text{map} < 1$	Van Genuchten parameter α layer 1
GenuAlpha1 for other	alpha1_other.map	U.: [-] R.: $0 < \text{map} < 1$	Van Genuchten parameter α layer 1
GenuAlpha2 for forest and other	alpha2.map	U.: [-] R.: $0 < \text{map} < 1$	Van Genuchten parameter α layer 2
Sat1 for forest	ksat1_forest.map	U.: [cm day ⁻¹] R.: $1 \leq \text{map} \leq 100$	Saturated conductivity layer 1
Sat1 for other	ksat1_other.map	U.: [cm day ⁻¹] R.: $1 \leq \text{map} \leq 100$	Saturated conductivity layer 1
Sat2 for forest and other	ksat2.map	U.: [cm day ⁻¹] R.: $1 \leq \text{map} \leq 100$	Saturated conductivity layer 2

CHANNEL GEOMETRY			
Map	Default name	Units, range	Description
Channels	chan.map	U.: [-] R.: 0 or 1	Map with Boolean 1 for all channel pixels, and Boolean 0 for all other pixels on MaskMap
ChanGrad	changrad.map	U.: [m m ⁻¹] R.: map > 0 !!!	Channel gradient
ChanMan	chanman.map	U.: [-] R.: map > 0	Manning's roughness coefficient for channels
ChanLength	chanleng.map	U.: [m] R.: map > 0	Channel length (can exceed grid size, to account for meandering rivers)
ChanBottomWidth	chanbw.map	U.: [m] R.: map > 0	Channel bottom width
ChanSdXdY	chans.map	U.: [m m ⁻¹] R.: map ≥ 0	Channel side slope Important: defined as horizontal divided by vertical distance (dx/dy); this may be confusing because slope is usually defined the other way round (i.e. dy/dx)!
ChanDepth Threshold	chanbnkf.map	U.: [m] R.: map > 0	Bankfull channel depth
DEVELOPMENT OF VEGETATION OVER TIME			
Map	Default prefix	Units, range	Description
LAIMaps for forest	lai_forest	U.: [m ² m ⁻²] R.: map ≥ 0	Pixel-average Leaf Area Index for forest
LAIMaps for other	lai_other	U.: [m ² m ⁻²] R.: map ≥ 0	Pixel-average Leaf Area Index for other

Necessary maps for LISFLOOD but not treated in this report.
 Meteorological input is covered in Ntegeka et al 2013.

Reporting stations			
Map	Default prefix	Units, range	Description
Outlets Maps	outlets.map	[-]	Reporting stations for e.g. discharge
Sites maps	sites.map	[-]	Reporting stations for special sites

METEOROLOGICAL VARIABLES			
Map	Default prefix	Units, range	Description
Precipitation Maps	pr	U.: [mm day ⁻¹] R.: map ≥ 0	Precipitation rate
TavgMaps	ta	U.: [°C] R.: -50 ≤ map ≤ +50	Average <i>daily</i> temperature\
E0Maps	e	U.: [mm day ⁻¹] R.: map ≥ 0	Daily potential evaporation rate, free water surface
ES0Maps	es	U.: [mm day ⁻¹] R.: map ≥ 0	Daily potential evaporation rate, bare soil
ET0Maps	et	U.: [mm day ⁻¹] R.: map ≥ 0	Daily potential evapotranspiration rate, reference crop

Annex 5: LISFLOOD NetCDF format

0. General remarks

In general the resulting maps stick to the NetCDF conventions stated by the NetCDF Climate and Forecast (CF) Metadata Conventions. The last version is 1.6 released in December, 2011.

<http://cfconventions.org/>

<https://github.com/cf-convention/cf-documents/blob/master/cf-conventions/1.6/cf-conventions.pdf>

The conventions define metadata that provide a definitive description of what the data in each variable represents, and of the spatial and temporal properties of the data. Because it was mainly done for climate and forecasting purpose some of our hydrological data are not taken into account.

Please find the link for standard-names here:

<http://cfconventions.org/standard-names-26.html>

You can find an online CF Compliance Checker here:

<http://puma.nerc.ac.uk/cgi-bin/cf-checker.pl>

For LISFLOOD applications we are using 2 projection and coordinate systems:

- For Europe: ETRS89 / ETRS-LAEA

<http://spatialreference.org/ref/epsg/etrs89-etrs-laea/>

on a 5km grid (replacing the GISCO LAEA projection)

- Global layers (also continents other than Europe) are given in geographic coordinates (lat/lon)

WGS1984 (<http://spatialreference.org/ref/sr-org/14/>) on a 0.1 degree grid

1. Europe
 - a.) Static maps (e.g. digital elevation model)

Format	Netcdf3_Classic (no compression possible) (to be compatible with ArcGIS)
Size	col: 1000, row: 950, size: 950000
Grid cell	5km, Unit: Meter
Projection	ETRS89 LAEA
Extend	Left: 2500000 Right: 7500000 Top: 5500000 Down: 750000
Variable: x	standard_name: projection_x_coordinate long_name: x coordinate of projection units: Meter Min, max: 2502500, 7497500
Variable: y	standard_name: projection_y_coordinate long_name: y coordinate of projection units: Meter Min, max: 752500, 5497500
Variable: laea	grid_mapping_name: lambert_azimuthal_equal_area earth_radius: 0 longitude_of_projection_origin: 10 latitude_of_projection_origin: 52 (and some other information but not mandatory)
Variable: time	Not mandatory because static maps does not have a time stamp
Variable: [value]	Name of [value] is defined by the name of the netcdf file till first 0 or . e.g. dem.nc = dem, std_elevation.nc = std_elevation standard_name: see http://cfconventions.org/standard-names-26.html long_name: can be own definition (but without blanks) units: depending on the [value] grid_mapping: lambert_azimuthal_equal_area esri_pe_string: PROJCS["ETRS_1989_LAEA",GEOGCS["GCS_ETRS_1989",DATUM["D_ETRS_1989",SPHEROID["GRS_1980",6378137.0,298.257222101]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Lambert_Azimuthal_Equal_Area"],PARAMETER["false_easting",4321000.0],PARAMETER["false_northing",3210000.0],PARAMETER["central_meridian",10.0],PARAMETER["latitude_of_origin",52.0],UNIT["Meter",1.0]]

a.) Time depending maps stacks (e.g. precipitation)

Format	Netcdf4 (compression zlib=True,least_significant_digit=2) (Netcdf4 because netcdf3 cannot be compressed)
Size	col: 1000, row: 950, size: 950000
Grid cell	5km, Unit: Meter
Projection	ETRS89 LAEA
Extend	Left: 2500000 Right: 7500000 Top: 5500000 Down: 750000
Variable: x	standard_name: projection_x_coordinate long_name: x coordinate of projection units: Meter Min, max: 2502500, 7497500
Variable: y	standard_name: projection_y_coordinate long_name: y coordinate of projection units: Meter Min, max: 752500, 5497500
Variable: laea	grid_mapping_name: lambert_azimuthal_equal_area earth_radius: 0 longitude_of_projection_origin: 10 latitude_of_projection_origin: 52 (and some other information but not mandatory)
Variable: time	standard_name: time units: days since 1990-01-01 00:00:00 calendar: proleptic_gregorian
Variable: [value]	Name of [value] is defined by the name of the netcdf file till first 0 or . e.g. pr.nc = pr, ta000000.001.nc = ta standard_name: see http://cfconventions.org/standard-names-26.html long_name: can be own definition (but without blanks) units: depending on the [value] grid_mapping: lambert_azimuthal_equal_area esri_pe_string: PROJCS["ETRS_1989_LAEA",GEOGCS["GCS_ETRS_1989",DATUM["D_ETRS_1989",SPHEROID["GRS_1980",6378137.0,298.257222101]],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTION["Lambert_Azimuthal_Equal_Area"],PARAMETER["false_easting",4321000.0],PARAMETER["false_northing",3210000.0],PARAMETER["central_meridian",10.0],PARAMETER["latitude_of_origin",52.0],UNIT["Meter",1.0]]

2. World

b.) Static maps (e.g. digital elevation model)

Format	Netcdf3_Classic (no compression possible) (to be compatible with ArcGIS)
Size	col: 3600, row: 1500, size: 5400000
Grid cell	0.1°, Unit: degree
Projection	GCS_WGS_1984 (not explicitly stated but it seems to be the default)
Extend	Left: -180 Right: 180 Top: 90 Down: -60
Variable: lon	standard_name: longitude coordinate long_name: longitude coordinate units: degrees_east Min, max: -179.95, 179.95
Variable: lat	standard_name: latitude long_name: latitude coordinate units: degrees_nord Min, max: -59.95, 89.95
Variable: time	Not mandatory because static maps does not have a time stamp
Variable: [value]	Name of [value] is defined by the name of the netcdf file till first 0 or . e.g. dem.nc = dem, std_elevation.nc = std_elevation standard_name: see http://cfconventions.org/standard-names-26.html long_name: can be own definition (but without blanks) units: depending on the [value] esri_pe_string:GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137,298.257223563]],PRIMEM["Greenwich",0],UNIT["Degree",0.0174532925199433]]

b.) Time depending maps stacks (e.g. precipitation)

Format	Netcdf4 (compression zlib=True,least_significant_digit=2) (Netcdf4 because netcdf3 cannot be compressed)
Size	col: 3600, row: 1500, size: 5400000
Grid cell	0.1°, Unit: degree
Projection	GCS_WGS_1984
Extend	Left: -180 Right: 180 Top: 90 Down: -60
Variable: lon	standard_name: longitude coordinate long_name: longitude coordinate units: degrees_east Min, max: -179.95, 179.95
Variable: lat	standard_name: latitude long_name: latitude coordinate units: degrees_nord Min, max: -59.95, 89.95
Variable: time	standard_name: time units: days since [year-month-day] 00:00:00 (depending on the first map calendar: proleptic_gregorian
Variable: [value]	Name of [value] is defined by the name of the netcdf file till first 0 or . e.g. pr.nc = pr, ta000000.001.nc = ta standard_name: see http://cfconventions.org/standard-names-26.html long_name: can be own definition (but without blanks) units: depending on the [value] esri_pe_string:GEOGCS["GCS_WGS_1984",DATUM["D_WGS_1984",SPHEROID["WGS_1984",6378137,298.257223563]],PRIMEM["Greenwich",0],UNIT["Degree",0.0174532925199433]]

Picture credits

Coverpage: River network 5km – East Sicily

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Abstract

This technical report describes the static input layers for the LISFLOOD model. The LISFLOOD model is a hydrological rainfall-runoff model that is capable of simulating the hydrological processes that occur in a catchment.

The data set contains gridded numerical information related to topography, channel geometry, land cover and soil characteristics at a pan-European scale. This report gives a summary of the source geo-spatial data sets, the applied methodology and the characteristics of the resulted data.

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