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Report on produced land cover datasets and Report on data production and accuracy assessment

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Action

Action 11 – Evaluation of required North-Eurasian land cover information

LIFE+ PROJECT NAME or Acronym

SNOWCARBO

Pekka Härmä, Markus Törmä, Suvi Hatunen, Tiina Markkanen

Name Beneficiary	Finnish Environment Institute (SYKE)
Contact person	Pekka Härmä
Postal address	Mechelininkatu 34a, P.O.Box 140, FI-00251, Helsinki
Telephone	+358 400 148 755
Fax:	+358 9 5490 2690
E-mail	Pekka.harma[at]ymparisto.fi
Project Website	http://snowcarbo.fmi.fi

Table of contents

List of abbreviations

CLC	CORINE land cover
CLC2000	CORINE Land Cover 2000
CORINE	Coordinated
COSMOS	Community Earth System Models (network for earth system modelling)
DEM	Digital elevation model
ECHAM5	European Centre Hamburg Model (global circulation model, atmosphere)
ENVISAT	Environmental satellite
IMAGE2000	Satellite image database for pan-European image coverage for 2000 (±1y)
JSBACH	Jena Scheme for Biosphere-Atmosphere (model describing biosphere-atmosphere interaction)
LAI	Lead area index
LSP	Land surface parameter
LSS	Land surface schemes
MERIS	Medium resolution imaging satellite
MODIS	Medium Resolution Image Spectrometer
MPI-M	Max Planck Institute on meteorology
NDVI	Normalized difference vegetation index
NLS	National Land Survey
REMO	Regional climate model
SYKE	Finnish Environment Institute
TOA	Top of the atmosphere
USGS	United States Geological Survey

Summary

Land surface characteristics used in the standard versions of climate models in SnowCarbo project are mapped using global 1km resolution land cover dataset[9, 14, 15]. The feasibility of these data in the Nordic conditions of Scandinavia is reported and production of alternative, more feasible regional land cover data sets are described in this document. The document is largely based on a conference article presented in SPIE European Remote Sensing conference, Toulouse 20-23.9.2010[23].

1 Introduction and objectives

The climate models together with their land surface schemes (LSS) are used for estimating present day CO2 balance of Northern Europe. The goal of the project is to improve the model predictions facilitating a variety of Earth Observation (EO) and in situ data in constraining and calibrating the models. Also, CO2 balance maps will be produced by combining different earth observation data sources and modelling. The core region for which the most extensive set of model simulations and evaluations of model performance will be carried out covers Scandinavia and Baltic countries. However, as the available EO data covers northern Eurasia in whole, the ultimate aim of the project is to provide insight into the quality of the climate and CO2 balance predictions of the Northern Hemisphere. The climate models of Max Planck Institute on meteorology (MPI-M, Hamburg) are used for climate and CO2 exchange simulations. The present version of general circulation model of MPI-M is ECHAM5 whose LSS is called JSBACH. A REgional climate MOdel (REMO) of MPI-M in its present form lacks a LSS capable of simulating CO2 cycle. Thus JSBACH will be used for predicting the terrestrial CO2 exchange with the regional model as well.

In standard model versions the vegetation cover data is a global 1km resolution land cover dataset by Hagemann [9, 10] based on Olson ecosystem classification [14, 15]. This land cover class data is unambiguously related to following parameters: background surface albedo, fractional vegetation cover, leaf area index (LAI), forest ratio, roughness length, and water holding capacity.

Land cover classification give the spatial distribution of land cover types and surface parameters allocated for each land cover type shows the characteristics of each land cover category used by the models. The aim of this report is to present different alternatives for land cover classification data needed in climate and carbon balance modelling. Additionally the feasibility of selected surface parameters (Forest ratio and LAI) is evaluated using local estimates in Nordic conditions.

2 Olsson ecosystem classification

ECHAM and REMO use Olson ecosystem classification for their land cover information. It represents the Earth's seasonal land cover in a consistent global framework by identifying 94 ecosystem types. The objective has been to distinguish seasonal land cover of the biosphere as a whole, integrating vegetation structure, seasons, climate and plants. The classification has been based on definitions given by Olson [14, 15] and made by U.S. Geological Survey using NOAA AVHRR 10-day mosaics with 1 km spatial resolution from April 1992 to March 1993 of International Geosphere Biosphere Programme [9, 10].

First, monthly maximum NDVI-mosaics have been computed and these classified using clustering analysis. Global digital elevation model and ecological regions data have been used for identifying land cover types and stratifying seasonal regions representing two or more disparate vegetation types. Maps and atlases of ecoregions, soils, vegetation, land use, and land cover have been used in the interpretation phase of the study and serve as reference data to guide class labeling[7].

For climate modeling purposes following surface parameters have been allocated to each class: background surface albedo αs, surface roughness length due to vegetation z0,veg, fractional vegetation cover cv and leaf area index LAI for the growing (g) and dormancy season (d), forest ratio cf, plant-available soil water holding capacity Wava, and volumetric wilting point fpwp [9, 10].

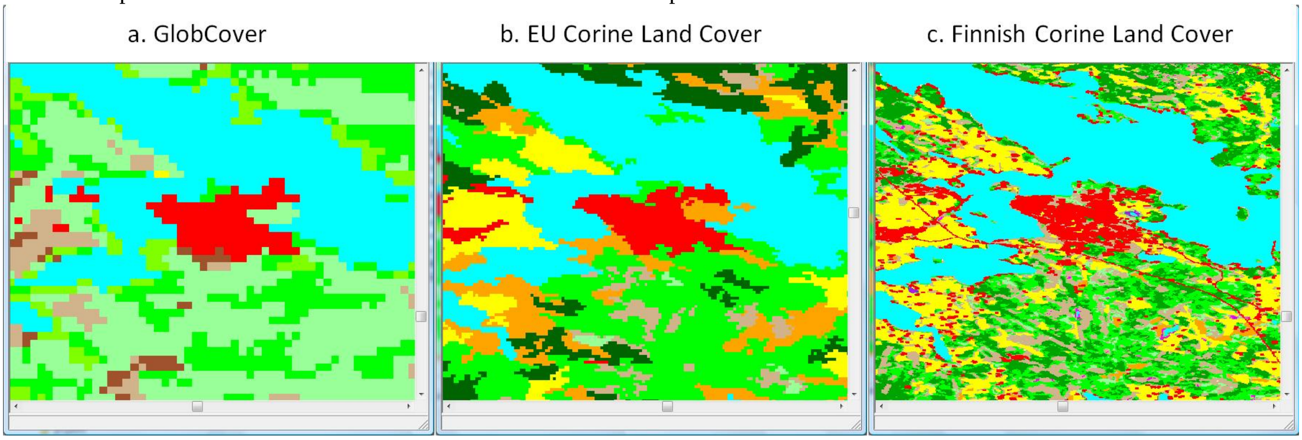
The surface data is aggregated into surface maps of the size and resolution of the prospective domain. For most of the parameters the preprocessing steps consist of weighed areal averaging but for some, such as roughness length, the processing is more complicated [10]. In the Nordic areas the aggregation of two parameters - soil field capacity and fractional vegetation which is related to forest ratio - is modified to account for region specific vegetation and soil features. Field capacity is typically high in wide areas of forested wet lands in Finnish and Swedish Lapland, where the land cover is boreal coniferous forest whose allocated soil field capacity is 0.21 that is too low for the soils. Thus the value is overwritten with a constant value of 0.71 according to the distribution of class 15 of the FAO/Unesco soil type dataset [10]. The fractional vegetation cover of the land cover class boreal coniferous forest is increased from 0.52 to 0.91 in Fennoscandia.

3 Revision of land cover classification

Since Olsson land cover data sets are quite outdated and recently produced global, regional and local land cover classifications are available, new sets of land cover information were produced for the modelling.

Following land cover information were used: The regional version 2.2 of GlobCover land cover classification (Bicheron 2008), Corine Land Cover classification in its European and Finnish forms (CLC2000), and Leaf Area Index [26] and Albedo-products [30] of MODIS-remote sensing instrument. These were used to create alternative classifications for modeling purposes. Figure 2 represents an example of different land cover classifications.

Figure 1. An example of different land cover classifications, GlobCover with 300 m pixel size, European Corine Land Cover with 100 m pixel and Finnish national Corine Land Cover with 25 m pixel.



3.1 GlobCover

Global land cover classification GlobCover is based on ENVISAT's Medium Resolution Imaging Spectrometer (MERIS) Level 1B data acquired in Full Resolution mode with a spatial resolution of 300 meters. For the generation of the Level 1B data, the raw data acquisitions have been geometrically corrected and resampled on a path-oriented grid, with pixel values having been calibrated to match the Top Of Atmosphere (TOA) radiance. Then, cloud and snow detection is made to images, they are mosaiced and mosaics classified. Different geographical regions can have their own more detailed classes [6].

3.2 Corine Land Cover

Corine Land Cover (CLC) classification is pan-European project aimed at gathering information relating to the environment on certain priority topics for the European Union (Land cover, Coastal Erosion, Biotopes etc). The classification has been produced using satellite images and visual interpretation, previously using Landsat TM/ETM-images and the latest one using Spot XS and IRS LISS-images. The mapping scale is 1:100 000 and mapping accuracy at least 100 m. The minimum mapping unit is 25 hectares and minimum width of units 100 m. Only area elements are classified. The classification nomenclature is hierarchical and contains five classes at the first level, 15 classes at the second level and 44 classes at the third level[4]. There can also be national level 4 classes.

Finnish national CLC classification is a combination existing digital map data and land cover interpretation based on IMAGE2000[11] (Landsat ETM) or IMAGE2006[8] (IRS/Spot). The land cover interpretation has been performed by estimating various variables describing tree and vegetation cover for each image pixel and thresholding these to CLC classes. Classes related to land use have been created by recoding digital map data to CLC classes and in some cases updating them with satellite images. The result is a raster database with a resolution of 25 m by 25 m, including additional raster datasets describing the origin and date of data in each pixel. Table 1 presents the level 2 classes in Finland and their proportions, as well as level 3 classes. European version with 25 ha minimum mapping unit has been created using generalizing Arc/Info-macros[11]. In principle, Finnish CLC 2000 and 2006 have been produced same way, but there are some differences because some databases have been more up-to-date and of better quality. Main difference is classification of Lapland, which is based on decision tree classifier and better use of GIS-data in new version[8].

Table 1. Corine land cover classes on level 2 and their proportions from Finnish Territory. Also level 3 classes are listed.

Code	CLC level 2 class	Prop (%)	Level 3 classes
1.1	Urban fabric	1.5	111 Continuous urban fabric, 112 Discontinuous urban fabric
1.2	Industrial, commercial and transport units	0,.7	121 Industrial or commercial, 122 Road and rail networks, 123 Port areas, 124 Airports
1.3	Mine, dump and construction sites	0.1	131 Mineral extraction, 132 Dump sites, 133 Construction sites
1.4	Artificial non-agricultural vegetated area	0.6	141 Green urban areas, 142 Sport and leisure facilities
2.1	Arable land	5.8	211 Non-irrigated arable land
2.2	Permanent crop	0.0	222 Fruit trees and berry plantations
2.3	Pasture	0.2	231 Pastures
2.4	Heterogeneous agricultural area	0.6	242 Complex cultivation, 243 Land principally occupied by agriculture, with significant areas of natural vegetation
3.1	Forest	43.7	311 Broad-leaved, 312 Coniferous, 313 Mixed
3.2	Shrubs and/or herbaceous vegetation	17.4	321 Natural grassland, 322 Moors and heathland, 324 Transitional woodland/shrub
3.3	Open spaces with little or no vegetation	0.5	331 Beaches, dunes, sand, 332 Bare rock, 333 Sparsely vegetated areas
4.1	Inland wetland	7.0	411 Inland marshes, 412 Peatbogs
4.2	Coastal wetland	0.1	421 Salt marshes
5.1	Inland water	8.5	511 Water courses, 512 Water bodies
5.2	Sea water	13.4	523 Sea and ocean

CLC2006 is regarded as the most accurate and harmonized land cover data covering almost whole of Europe, since the data is interpreted using high resolution satellite data together with diverse local GIS databases. The data are produced by national experts who are familiar with local conditions and have access to the most accurate existing data sources of land cover.

3.3 MODIS-products

MODIS (Moderate Resolution Imaging Spectroradiometer) is American remote sensing instrument onboard of NASA'a Terra and Aqua satellites. Instrument has 36 spectral bands in visible and infrared regions; spatial resolution is 250, 500 or 1000 m depending on band and temporal resolution 1 or 2 days. In order to enhance the data usability, acquired data has been processed to predefined products, MOD15 Leaf Area Index and MCD43 Albedo, which two are used in this study.

MOD15 product is estimated Leaf Area Index (LAI) and Fractional Photosynthetically Active Radiation (FPAR). Fraction of Absorbed Photosynthetically Active Radiation is radiation that a plant canopy absorbs for photosynthesis and growth in the 0.4 – 0.7 µm spectral range and it is expressed as a unitless fraction of the incoming radiation received by the land surface. Leaf Area Index is the biomass equivalent of FPAR, and is also a dimensionless ratio (m2/m2) of leaf area covering a unit of ground area. Both of these variables are computed daily at 1 km from MODIS spectral reflectances for all vegetated land surface globally. Estimation is based on canopy radiation model, but if that does not converge, then empirical relationships between NDVI are used. 8-day composite mosaic based on maximum FPAR of LAI has been used in this study.

MODIS BRDF/Albedo Product[30] (Product MCD43) provides differently processed albedos as well as surface reflectances corrected to a common nadir view geometry at the local solar noon zenith angle. The albedo of a surface describes the ratio of radiant energy scattered upward and away from the surface in all directions to the downwelling irradiance incident upon that surface. Every 8 days, the operational MODIS BRDF/Albedo algorithm makes use of 16 days worth of multi-date data from both Terra and Aqua and a semiempirical kernel-driven bidirectional reflectance model to determine a global set of parameters describing the BRDF of the land surface. These 500m gridded parameters are then used to determine directional hemispherical reflectance ("black-sky albedo"), and bihemispherical reflectance ("white-sky albedo") for seven spectral bands (MODIS channels 1-7) and three broad bands (0.3-0.7µm, 0.7-5.0µm, and 0.3-5.0µm) at the solar zenith of local solar noon. The nadir BRDF-adjusted surface reflectances (NBAR) for the seven spectral bands are also computed for local solar noon. Broad band albedos for wavelenghts 0.3-0.7 µm and 0.7-5.0 µm have been used in this study.

New classification was created using MODIS-products and GlobCover-classification. Used MODIS-products were MOD15 Leaf Area Index (8-day composite mosaic) and MCD43 visible and infra-red Albedos (16-day composites). Mosaics for years 2007 and 2008, months March – October, were downloaded from Glovis (USGS Global Visualization Viewer, http://glovis.usgs.gov/). Then monthly mean values were computed for LAI, and VIS and IR Albedos, and their minimum and maximum values selected for classification. Also, rough estimate of forest cover was done using GlobCover classification by defining forest cover proportion for each class. These seven features were clustered to 50 clusters using unsupervised classification algorithm of Erdas Imagine 9.3. Clusters were interpreted using Finnish national Corine Land Cover and GlobCover, and appropriate class of Olson classification selected. Finally, because there was some confusion between water areas and bare ground areas, water areas were taken from GlobCover classification.

3.4 Comparison of different alternatives for land cover data

Since land cover must be mapped both in REMO and JSBACH with Olsson nomenclature, revised land cover data sets were recoded into Olsson nomenclature. This was completed by comparing class definions in different data sets and with the aid of surface parameters allocated for each land cover category in the Olsson data.

Olson ecosystem classification and Corine Land Cover in Finland

Table 2 represents the classes of Olson ecosystem classification which exist within Finnish territory, and the largest classes of Finnish national Corine Land Cover 2000 classification[11] within each class of Olson ecosystem classification for comparison. In all, there are 29 different classes of Olson within Finnish territory, but only three classes (21. Conifer Boreal Forest, 15. Sea Water, 23. Cool Mixed Forest) cover 69% from this area. There are seven other classes with individual proportions 1 – 10 % that cover 28% from Finnish area. The rest, 19 classes cover about 3%.

Areawise, the proportion of water is quite similar in Olson and Corine. Proportion of forests is larger in Olson, but otherwise proportions of other main land cover groups (urban areas, agricultural areas, transitional woodlands and open lands) are smaller in Olson than Corine. One large failure is that there are no open bogs, mires and marshes in Olson classification of Finland.

Almost half of Inland water is something else than water on CLC. This is because of Finland has many small lakes with long shorelines. Quite often agricultural areas in Corine are in forest classes of Olson, this is because Finnish landscape is mosaic of small polygons with different land covers and uses. Also the open bogs of Corine have usually been classified as forest in Olson.

Table 2. Classes of Olson ecosystem classification within Finnish territory, their proportions, the most common Finnish National Corine 2000 Land Cover classes (see table 1 for class names) within those Olson classes, and which GlobCover (table 3) or Corine (table 1) classes have been recoded to which Olson classes.

Nr	Olson class	Prop. (%)	The most common Corine 2000 classes	GlobCover recoded	Corine recoded
1	Urban	0.03	1.1, 1.2	190	111, 121, 122, 123, 131, 132, 133
2	Low Sparse Grassland	0.03	3.1 (3.1.2 / 3.1.3), 5.1		
4	Deciduous Conifer Forest	3.2	3.1 (3.1.3 / 3.1.2), 3.2, 4.1	91	
8	Bare Desert	0.01	3.3, 3.2	201	
9	Upland Tundra	0.01	3.2, 3.3		
11	Semi Desert	-		200	
12	Glacier Ice	>0.01	3.3	220	
13	Wooded Wet Swamp	-		180	
14	Inland Water	9.8	5.1, 2.1, 3.1	210	511, 512
15	Sea Water	14.2	5.2		523
16	Shrub Evergreen	-		131	
17	Shrub Deciduous	3.2	3.1 (3.1.2 / 3.1.1 / 3.1.3), 3.2, 4.1	134	
19	Evergreen Forest and Fields	0.01	3.1 (3.1.3 / 3.1.2), 2.1, 3.2		
21	Conifer Boreal Forest	44.6	3.1 (3.1.2 / 3.1.3), 3.2	70, 90, 92	312
22	Cool Conifer Forest	0.1	2.1, 3.1		
23	Cool Mixed Forest	10.2	3.1 (3.1.2 / 3.1.3), 3.2	101	313
25	Cool Broadleaf Forest	-		50, 60	141, 311
30	Cool Crops and Towns	-			112, 124, 142
31	Crops and Town	0.02	1.1, 2.1, 3.1 (3.1.2 / 3.1.3)		
38	Cool Irrigated Cropland	>0.01	3.1 (3.1.2), 3.2, 2.1, 1.4		
40	Cool Grasses and Shrubs	-		120	321
42	Cold Grassland	0.7	3.2	150, 151, 152, 140, 141	231
44	Mire, Bog, Fen	-		185	412
45	Marsh Wetland				411, 421
47	Dry Woody Shrub	-			324
50	Sand Desert			202	331
51	Semi Desert Shrubs	>0.01	5.1		
53	Barren Tundra	0.07	3.3, 3.2		333
55	Cool Fields and Woods	0.3	3.1 (3.1.2 / 3.1.3), 2.1, 3.2	20	
56	Forest and Field	0.08	3.1 (3.1.2 / 3.1.3), 3.2, 2.1		
57	Cool Forest and Field	0.8	3.1 (3.1.2 / 3.1.3), 2.1, 3.2	32, 110	
60	Small Leaf Mixed Woods	1.7	3.2, 3.1 (3.1.1), 4.1		
61	Deciduous and Mixed Boreal Forest	1.6	3.1 (3.1.2 / 3.1.3), 3.2, 2.1	100	
62	Narrow Conifers	6.8	3.1 (3.1.2 / 3.1.3), 3.2, 2.1		
63	Wooded Tundra	0.6	3.2, 3.3		
64	Heath Scrub	0.1	3.2, 3.1 (3.1.2), 3.3, 5.1		322
69	Polar and Alpine Desert	>0.01	3.3, 3.2		332
93	Grass Crops	1.7	3.1 (3.1.2 / 3.1.3), 3.2, 2.1		211

94	Crops, Grass, Shrubs	0.07	3.1 (3.1.2), 3.2, 5.1	14, 21, 30	222, 243

Globcover and Corine Land Cover in Finland

Table 3 represents the classes of GlobCover classification which exist within Finnish territory, and the largest classes of Finnish national Corine Land Cover 2000 classification within each class of GlobCober classification for comparison. In all, there are 14 different classes of GlobCover within Finnish territory. Five classes dominate; their proportion is about 93% together. There are two classes with proportion 1-10%, together about 6% proportion. The rest, 7 classes cover about 1%. Areawise, the proportion of water is quite similar in GlobCover and Corine. Proportion of forests is considerably larger in GlobCover than in Corine, but this proportion is better than with Olson. Otherwise, the proportions of land cover types are smaller than in Corine but better than in Olson. The largest mistake is with agricultural areas; their proportion is very small in GlobCover. As conclusion, areawise GlobCover represents the Finnish territory better than Olson. Classwise, there are some GlobCover classes, which are largely covered by water according to Corine but their proportions are quite small. The largest mistake is with class 150 Sparse vegetation, it contains most of the agricultural areas of Corine. Quite often, the forest classes of GlobCover contain quite much shrubby areas.

Table 3. Classes of GlobCover classification within Finnish territory, their proportions and Finnish National Corine Land Cover classes (see table dd for class names) within those GlobCover classes.

Nr	GlobCover Class	Prop. (%)	The most common Corine classes
14	Rainfed croplands	0.003	2.1, 5.1, 3.1 (3.1.3 / 3.1.2)
20	Mosaic cropland (50-70%) / vegetation (20-50%)	0.03	5.2, 5.1, 3.1 (3.1.2 / 3.1.3)
30	Mosaic vegetation (50-70%) / cropland (20-50%)	0.00005	5.2
50	Closed (>40%) broadleaved deciduous forest (>5m)	11.9	3.1 (3.1.3 / 3.1.2), 3.2, 2.1
70	Closed (>40%) needleleaved evergreen forest (>5m)	0.03	3.1 (3.1.2), 5.2, 5.1
90	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)	27.1	3.1 (3.1.2 / 3.1.3), 3.2
100	Closed to open (>15%) mixed broadleaf and needleleaf forest (>5m)	21.8	3.1 (3.1.2 / 3.1.3), 3.2
110	Mosaic forest or shrubland (50-70%) / grassland (20-50%)	3.2	3.1 (3.1.2 / 3.1.3), 2.1, 3.2
140	Closed to open (>15%) herbaceous vegetation	0.003	2.3, 5.2
150	Sparse (<15%) vegetation	12.9	3.2, 3.1 (3.1.2), 2.1, 4.1
180	Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil	3.0	4.1, 3.1 (3.1.2), 3.2
190	Artificial surfaces and associated areas (Urban areas >50%)	0.4	1.1, 1.2, 3.1 (3.1.2)
200	Bare areas	0.05	3.3
210	Water bodies	19.4	5.2, 5.1

Olsson, Globcover and Corine Land cover in Europe

Different sources of land cover data were evaluated also regionally in the area where Corine Land Cover 2006 data were available. Comparison was made by crosstabulating the data sets. Detailed land cover classifications were aggregated into five main land cover categories i.e. urban areas (artificial surfaces), agricultural areas, forests, wetlands and peatbods and water surfaces. The output shows the main differences of data sets (see tables 3 and 4).

Table 3. Comparison of GlobCover and Corine Land Cover 2006 in Europe by main land cover categories

%	clc_urban	clc_agri	clc_forest	clc_bog&wet	clc_water	total
GlobCover urban	24,7	0,7	0,2	0,1	0,7	1,4
GlobCover agri	43,5	40,7	13,9	4,3	3,8	24,1
GlobCover forest	30,6	58,0	84,4	70,5	21,6	70,3
GlobCover bog&wet	0,1	0,2	0,8	15,5	0,6	1,0
GlobCover water	1,0	0,3	0,7	9,5	73,3	3,3
total	4,2	35,4	54,5	2,5	3,5	100,0

Table 4. Comparison of Olsson and Corine Land Cover 2006 in northern Europe by main land cover categories

%	clc_urban	clc_agri	clc_forest	clc_bog&wet	clc_water	total
olson urban	17,7	0,3	0,1	0,0	0,1	0,4
olson agri	40,4	55,5	12,4	6,9	1,2	16,9
olson forest	32,1	40,6	81,7	82,4	5,7	51,2
olson bog&wet	0,0	0,0	0,0	0,0	0,0	0,03
olson water	9,8	3,6	5,7	10,6	93,1	31,5
total	1,6	17,7	47,1	4,0	29,6	100,0

The result shows differences in the distribution of land cover categories. Globcover overestimates the area of forests and underestimates the area of artificial surfaces and agricultural areas in Europe compared to CLC2006.

3.5 LC data for models

Since land cover must be mapped both in REMO and JSBACH with Olsson nomenclature, revised land cover data sets were recoded into Olsson nomenclature. This was completed by comparing class definions in different data sets and with the aid of surface parameters allocated for each land cover category in the Olsson data. Following processing was completed:

- GlobCover classification has been recoded to Olson classes (table 2, fifth column). Since the pixel size of GlobCover classification is 300 m, the data was resampled into 1000 m grid after majority filtering in 3x3 window.
- Corine Land Cover has been recoded to Olson classes. This recoding was made by searching the closest Olson class for Corine class (table 2, sixth column). Originally, European Corine Land Cover classification is vector data with 25 hectare minimum mapping unit. Rasterized version with 100 m pixel size was used in this study. Because of differences in pixel sizes (CLC 100 m, Olson 1000m), processing was made so that class recoding was made first, then majority-filtering with 9x9 filtering window and finally resampling to 1000 m pixel size.
- Finnish national Corine Land Cover[11,24] was used instead of European Corine in Finland. Processing goes as well as with European Corine, but size of majority filter was 41x41 pixels. Outside Finland, European Corine and GlobCover were used.

Different revised land cover data sets recoded into Olsson nomenclature were produced covering the modelling window in Scandinavia and surrounding areas. The land cover information were retrieved using:

1. GlobCover
2. European Corine Land Cover were available and Globcover elsewere
3. National Corine Land cover within Finland, European Corine Land Cover were available and Globcover elesewere
4. MODIS products

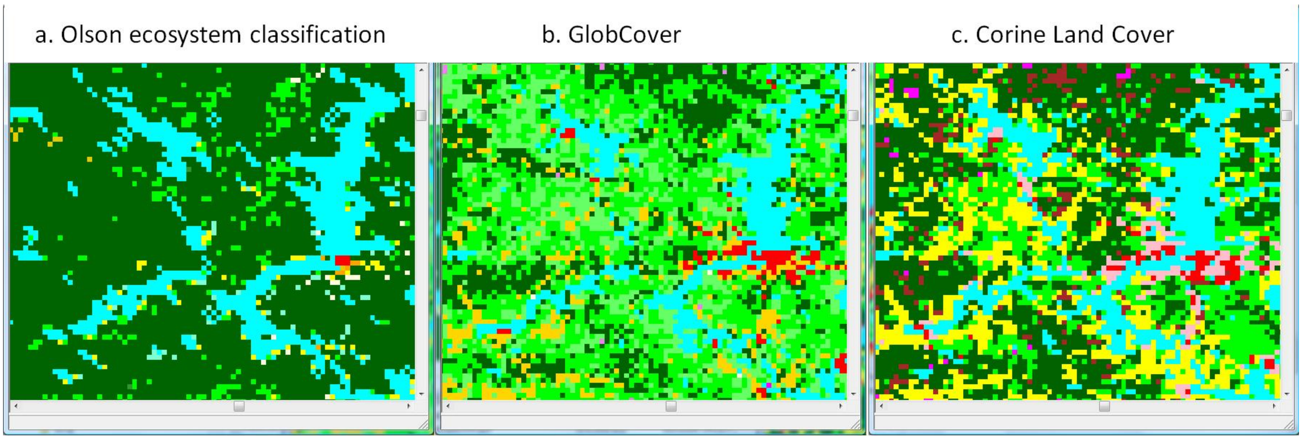


Figure 2. An example of different land cover data for modeling; a. original Olson ecosystem classification, b. classification based on recoding GlobCover classification (section 3.2.2), and c. classification based on recoding Corine Land Cover classification (section 3.2.3).

4 Evaluation of surface parameters

4.1 Comparison of forest ratio with crown cover

The surface parameter forest ratio (cf) is defined as the fractional cover of trees. This definition corresponds with forest characteristic crown cover. Since crown cover was estimated by Finnish Forest Research Institute in CORINE Land Cover 2006 project[11], it was possible to compare surface parameter forest ratio with crown cover in Finnish territory. Crown cover was estimated using field sample plots (about 45 000 totally within Finland) measured in National Forest Inventory and IMAGE2006 satellite data (IRS LISS and SPOT XS data) using specific k-NN classification method, which is developed and used operationally at Finnish Forest Research Institute[8]. The crown cover of trees (deciduous and coniferous tree species separately) has been estimated for each 25 meter grid cell for whole Finland in the range 0-100 %. Open, non-forested land cover classes were given crown cover 0 %, like agricultural areas, water bodies, open bogs etc.

The mean of crown cover for coniferous forests was calculated. The coverage of coniferous forests was defined by different land cover data sets and different scales (size of grid cell). When coniferous forest was mapped according to Finnish national CORINE data in 25 m resolution, the mean value for crown cover was 41 % for whole Finland. The density of forests varies within Finland in different vegetation zones: In northern boreal zone the average crown cover in forests was 32 %, while the corresponding figure for southern boreal zone was

51 %. When the coverage of coniferous forests was defined using Olson ecosystem classification (class 21 Coniferous boreal forests) with 1 km resolution, the mean of crown cover was only 27 %. Inaccuracy of delineation of coniferous forests in Olsson data and low resolution causes mixing of sparsely forested areas with dense forests in grid cells, which average out the crown cover values.

Figure 3 presents the forest ratios proposed for different classes of Olson ecosystem classification[7] (Forest_ratio_MPI) as well as forest ratios calculated using estimated crown cover within Finland[11] for same land cover categories defined using Olson 1km data and national 25 meter CORINE Land cover. The proposed value (corrected and improved) of forest ratio for Olson class 21 Conifer boreal forest is 0.44. This corresponds well with the average crown cover (41 %) in Finnish coniferous forests defined using Finnish national CORINE data with 25 m resolution. In mixed forests (class 23) the proposed value is much higher than estimated using crown cover.

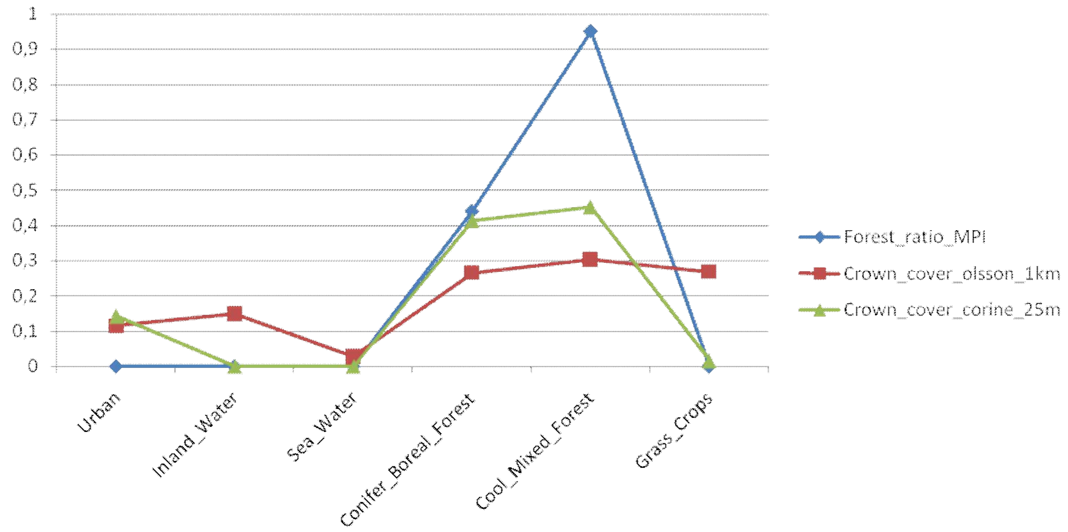


Figure 3. Proposed forest ratios for different classes of Olson ecosystem classification (Forest_ratio_MPI) as well as forest ratios calculated using estimated crown cover within Finland (Crown-cover_olsson_1km and Crown_cover-corine_25m).

4.2 Comparison of LAI

Reference data for the evaluation of Leaf area index (LAI) were obtained from VALERI project[31]. The objectives of the VALERI project are to provide high spatial resolution maps of biophysical variables (LAI, fAPAR, fCover) estimated using ground measurements to validate products derived from satellite observations.. Three sites in Finland[19, 20, 21] were selected for the comparison, which all represent boreal forest dominated by coniferous tree species.

Table 5. Characteristics of LAI measurements and applied satellite data in VALERI campaigns

site	date of field measurements	Number of field data plots (ESUs)	Variation in LAI	Satellite instrument used	date of satellite data acquisition
Hirsikangas	24/05/2005-22/06/2005	26	1.0 - 3.5	IRS P6 LISS-III	16/06/2005
Hyytiälä	18/06/2008-24/07/2008	43	0.2 - 3.5	SPOT4 HRVIR	30/07/2008
Rovaniemi	13/06/2005 – 17/06/2005	20	0.3-2.9	LANDSAT 5 TM	19/06/2005

Leaf Area Index was measured in the field using both LAI2000 instrument and hemispherical images processed with CAN-EYE software. High resolution maps of biophysical variables are produced by combining in-situ measurements with satellite data using empirical model. The RMSE of the models varied between 0.2-0.4. The characteristics of each site are described in table 5. High resolution LAI maps were produced using an image-window covering about 3 km by 3 km in each site. The geographical location of sites is plotted in figure 4.

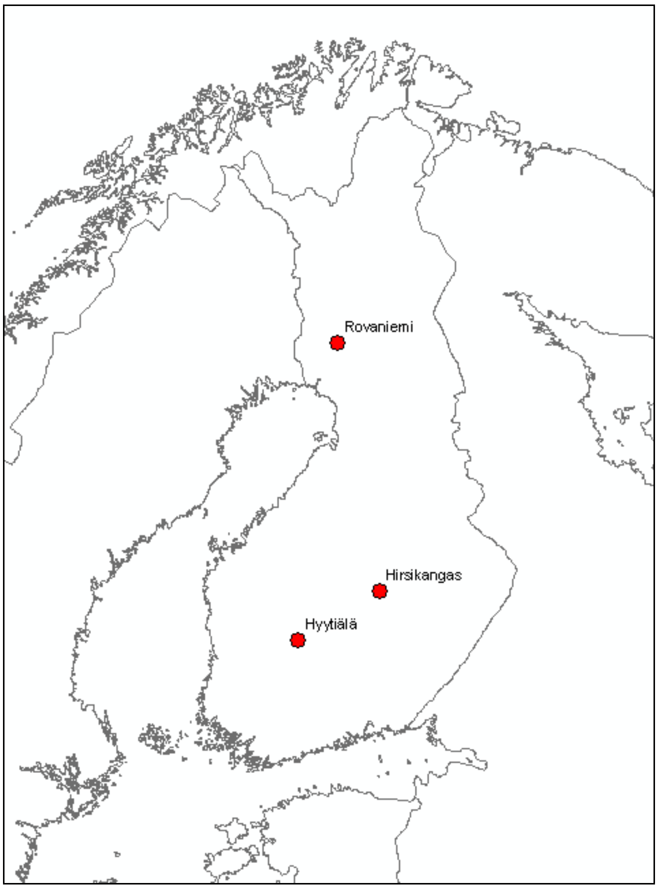


Figure 4. The location of VALERI sites

The high resolution LAI maps were combined with land cover map and maximum and mean LAI values during growing season were computed for each land cover category. Finnish national CLC2006 land cover map recoded into Olsson nomenclature with 25 meter resolution was used. The results are presented in table 6. below.

Table 6. Surface parameter LAI according to MPI report N0 289 and Valeri campaign in Finnish boreal forests

Class code	Global Ecosystem Legend	LAI growing season (MPI)	LAI dormancy season (MPI)	LAI_mean (Valeri)	LAI_max (Valeri)
21	Conifer Boreal Forest	5.5	5.5	1.8	4.1
23	Cool Mixed Forest	4.2	0.1	1.7	3.5
25	Cool Broadleaf Forest	5.2	0.51	1.6	3.6
47	Dry Woody Scrub	4.6	0.8	0.8	3.1

According to Table 6. LAI values during growing season proposed in MPI Report 289 are significantly higher than estimated using LAI vales measured in Valeri campaigns in Finnish coniferous forests. This is especially true if LAI is calculated as a mean value of LAI observations in different forest cover categories.

Conclusions

This report describes the new regional land cover data sets which are proposed to replace old global Olsson data. Several land cover data set were produced using Corine Land Cover, Globcover and MODIS data sets.

Models use Olson ecosystem classification for their land cover information. It has 94 classes and each class has own set of parameters describing the surface characteristics of each class and used by the models. When compared to Finnish national Corine Land Cover, the proportion of coniferous forests is larger in Olson and the proportion of other land cover types smaller. Due to large pixel size, the dominant land cover type is emphasized. Parameter forest ratio and LAI of Olson classification were studied further. It was noticed that usually the forest ratios of classes were quite much higher than forest crown cover estimates computed from high resolution satellite images. Also LAI for Olsson forest classes were higher than estimated using high resoltuin LAI maps produced in Valeri project.

Several alternatives for land cover data were constructed using GlobCover land cover classification, Corine Land Cover classification in its European and Finnish forms, and Leaf Area Index and Albedo-products of MODIS-remote sensing instrument. It was quite straightforward to recode GlobCover and Corine classifications to classes of Olson ecosystem classification, the main difficulty was to decided to correspondence between classes when the descriptions of classes were not that precise. Unsupervised classification of MODIS LAI and albedo products was more time-consuming.

When considering thematic accuracy of data, European and national version of Corine Land Cover should be used as input data source for land cover information over Scandinavia. However the feasibility of enhanced land cover information in models will be evaluated by comparing model outputs with in-situ carbon fluxes and EO based observations.

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