THE PRODUCTION OF FINNISH CORINE LAND COVER 2000 CLASSIFICATION

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ABSTRACT:

CORINE Land Cover is an Europeanwide land cover and land use classification which is based in most countries on visual interpretation of satellite images. The new CORINE2000 classification of Finland is based automated interpretation of satellite images and data integration with existing digital map data. Satellite images are used in estimation of continuous variables describing vegetation type and coverage, as well as in updating map data. Continuous land cover variables were transformed into discrete CORINE classes by thresholding there variables according to class descriptions in CORINE nomenclature. The output of Finnish CLC2000 project consists of calibrated IMAGE2000 mosaic, national CORINE classification (25 m raster) which is generalized and vectorized to European CORINE classification. According to the first validation utilization of non-standard, automated data production approach together with exploitation of existing digital map data was proved to be successful in Finnish conditions.

1. INTRODUCTION

The European Comission introduced the CORINE (Coordination of Information on the Environment) Programme in 1985 in order to gather information relating to the environment for the European Union. In order to determine and assess the effects of Community's environment policy, it is needed to have a proper understanding concerning the different features of the environment like the state and geographical distribution of individual environments and natural areas, the quality and abundance of water resources, Land cover and soil state, the amount of toxic discharges and natural hazards (Heymann et.al., 1994).

CORINE land cover classification is produced using satellite images. The mapping scale of this classification is 1:100 000 and mapping accuracy is at least 100 m. The minimum mapping unit is 25 hectares and minimum width of units is 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. The nomenclature has been developed in order to map the whole EU territory (Büttner et.al., 2002).

Originally, the land cover classification was performed as visual interpretation of hardcopy printout of satellite images. Digital image processing software was used to prepare the geometric, radiometric and spectral properties of satellite image so that the good hardcopy printout could be produced. A transparency was overlaid on 1:100000 printout of satellite image and areas were delineated and interpreted to the printout with the help of ancillary data like maps. Then the transparencies were digitized. Obviously, the procedure is prone to errors due to use of hardcopy products and digitization (Bossard et.al., 2000).

In order to update the CLC data European Environment Agency (EEA) and Joint Research Centre (JRC) launched the IMAGE2000 and CLC2000 project. The satellite image "snap shot" of the EU territory (IMAGE2000) will be the basic material to undertake the update of CLC database for the year 2000 (CLC2000) and identify main LC changes in Europe during the period 1990-2000. The project is also extended to the ten Phare Accession Countries which are also new EEA member countries from January 2002 (Krynitz, 2001).

The new CLC2000 database will be based on visual interpretation of Landsat ETM-images and ancillary data like existing topographic maps and aerial images. Interpretation work is carried out using GIS-software (Bossard et.al., 2000). As compared to the earlier version of CORINE land cover database, the updated version will be more time-consistent, more accurate and costs will be lower (Büttner et.al., 2002).

The main outputs of the IMAGE2000 and CORINE2000 projects at European level are (Krynitz, 2001):

- national and European wide satellite image mosaic for the year 2000,
- an updated national and European CORINE land cover classification for 2000, and
- a database of land cover changes between 1990 and 2000 at national and European levels.

Finnish Environment Institute (SYKE) is responsible for the project management and data production of CLC2000 in Finland. This includes selection of images in IMAGE2000, preprocessing and interpretation of satellite images, data fusion with GIS data, generalization, vectorization and accuracy assessment. Remote Sensing group in Technical Research Center of Finland (VTT Information Technology) provides methods and software for radiometric and atmospheric calibration of satellite images and image interpretation. Metsähallitus and UPM-Kymmene Ltd provide reference data for satellite image interpretation. Metsähallitus is a state enterprise who is responsible for the management of state owned land in Finland. UPM-Kymmene Ltd is an international private company focused on forest products.

Produced data will be a combination existing digital map data and land cover interpretation based on IMAGE2000. The land cover interpretation is performed by estimating various variables describing tree and vegetation cover for each image pixel and thresholding these to CLC-classes. The main data sources and their relation to the 1st level CORINE-classes are represented in figure 1. The output of the project includes satellite image mosaic over Finland (radiometrically and atmospherically corrected), national CLC data (25 meter raster) and European CLC data in vector format with minimum mapping unit of 25 hectares.

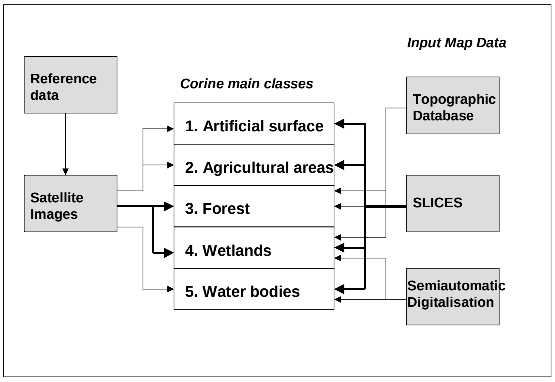

Figure 1. Main input data and CLC2000 main classes.

2. IMAGE2000

The output of the IMAGE2000 is a national satellite image mosaic for each country using a national map projection and European database in a European map projection (Krynitz, 2001).

2.1 Selected images

The satellite image coverage consists of Landsat-7 ETM-images from the summer 2000, and whenever necessary, it is complemented with images from 1999 and 2001 (Krynitz, 2001). The channels and spatial resolutions of Landsat-7 ETM are presented in table 1 (Kramer, 1996). The Finnish IMAGE2000 data consists of 36 LANDSAT 7 ETM+ FULL images processed by METRIA Sweden. This data provides almost full cloudfree coverage over Finland; data is missing only on 0.55% (170 000 ha) of the total land area of Finland.

The target year of IMAGE2000 was year 2000 and there are 12 images from that year. Other images are taken 1999 (9 images), 2001 (11 images) and 2002 (4 images). The earliest image is taken 29.7.1999 and the latest 11.8.2002. Images are taken during mid- or late growing season, 17 images are taken during July, 7 August and 7 September.

2.2 Geometric correction

The geometric correction of ETM-images was performed by Metria Sweden. This was done using satellite orbital parameters and ground control points. SYKE provided Metria shorelines of water bodies and digital elevation model for orthorectification. Ground control points were acquired as follows: lake center point ground coordinates were computed using digital map database 1:20 000 vector shoreline, lakes were interpreted from ETM-images and their center point image coordinates were computed and finally these ground and image coordinates were matched. Channels 1 – 5 and 7 were resampled to 25 m and panchromatic channel to 12.5 m grid using cubic convolution interpolation method.

The geometric correction was successful. The planimetric Root-Mean-Square-Error of test ground control points of images were quite small, the mean planimetric RMSE of images was 12.9 m and minimum and maximum RMSEs were 6.1 m and 18.9 m, respectively. The average number of test ground control points was 11 points per image, varying between 2 and 38 points.

Ch	Wavelen. (μm)	Spatial res. (m)	Ch	Wavelen. (μm)	Spatial res. (m)
1	0.45 – 0.52	30	5	1.55 – 1.75	30
2	0.52 – 0.60	30	6	10.4 – 12.5	60
3	0.63 – 0.69	30	7	2.08 – 2.35	30
4	0.76 – 0.90	30	Pan	0.50 – 0.90	15

Table 1. The channels and spatial resolutions of Landsat-7 ETM.

2.3 Detection of clouds and their shadows

Clouds and shadows were interpreted and digitized visually on screen using mainly bands 1,2 and 6. Vector polygons defining clouds and their shadows were rasterized into cloud-mask, which was used in mosaicing and interpretation of images.

2.4 Atmospheric correction

Atmosphere has its effect to the measurements made from satellites due to scattering and absorption of electromagnetic radiation. In order to decrease the effect of atmosphere, semiempirical correction method was developed by Technical Research Center of Finland. The correction is based on SMAC-algorithm (Parmes et. al 2004) and an independent atmospheric data, but parameters like aerosol optical thickness (AOD) can be retrieved from the image.

AOD seems to be the most important parameter affecting the atmospheric correction. The estimation of AOD is based on the ratio of channel 3 and channel 7 which should be 0.38 in the dense pine forest areas after atmospheric correction (Kaufman et.al., 1997). The dense forest areas were selected from old land cover database. These areas were further reduced according to the maximum reflectance and its variation in band 7 and the size of the area. The AOD value was estimated for each dense forest area by calculating the top-of-atmosphere reflectance of channel 7, calculating the target reflectance of channel 3 and deriving the AOD which would produce the desired reflectance. The final AOD can be the mean AOD value of all dense forest areas or AOD surface.

2.5 Topographic correction

Topographic height variations cause the variation of reflected radiation, because imaging geometry changes locally. Topographic correction is used to decrease the effect of these illumination differences. Several simple image based topographic correction methods were compared by correcting Landsat ETM image from Northern Lapland (Törmä and Härmä, 2003).

The chosen topographic correction method was Ekstrand correction (Ekstrand 1996). It was performed in the northernmost strata due to the relatively high height variations within that area. In the other areas of Finland the height variations are much smaller and smoother, so topographic correction was thought to be too time-consuming.

2.6 Mosaicking

The mosaicking of individual satellite images were carried out in order to get stratumwise (see figure 2) and nationwide mosaics for visualization purposes. Stratumwise mosaics will also be used for the interpretation process, so that the continuous variables are estimated for whole strata.

3. CORINE2000

3.1 Classification nomenclature

The CORINE nomenclature is hierarchical and it has five level 1 classes: artificial surfaces, agricultural areas, forest and seminatural surfaces, wetlands and water bodie. These are subdivided into 15 level 2 classes and 44 level 3 classes. There can also be national level 4 classes. More detailed description of the nomenlature can be found in Heymann et.al., 1994 and Bossard et.al., 2000.

3.2 Map data

The most important input map data are the SLICES land use element and digital topographic database 1:20 000.

3.2.1 SLICES: The SLICES Land use element is a combination of different national GIS databases owned and updated by different organizations (http://www.slices.nls.fi/). The sources for the database of SLICES land use element are:

- Finnish Land Parcel Identification System contains agricultural fields manually digitised from orthophotos. In addition, the data includes information on cultivated plants, fallow fields etc.
- Topographic database: See chapter 3.2.2.
- Railroad and road digital database (scale 1:20 000).
- Lakes, rivers, shorelines database (scale 1:20 000).
- Building and dwelling register

Separate data layers were stacked up into one database in specified order according to accuracy, importance and age of the data. There are 8 classes on the main level 1, 15 on the level 2, 34 level 3 and 48 level 4.

The output products of SLICES land use element are raster databases (10 x 10 m and 25 x 25 m). For every pixel, data source and mapping year are known. The age of the data mainly correspond to the year 1999-2000. SLICES Land Use element is used mainly in the production of artificial surfaces, agricultural land and water bodies-classes of CLC2000 (see figure 1).

3.2.2 Topographic database: The Topographical database includes the most accurate positional data about Finnish topography. It is comparable to maps on scale 1:5 000 - 1:10 000. The printed and digital map products of the National Land Survey are based on the Topographical database. The information covers the whole of Finland, except for the northernmost parts of Lapland (http://www.nls.fi/).

Following themes are utilized in the production of CLC:

- Waters (TopoWaters): Waters are divided into sea, lakes and flowing water courses in this database (TopoWaters).
- Peatlands (TopoPeatland): Peatlands are classified according to tree cover, accessibility and exploitation. Also areas with thin peat (< 0.3 m) layer are mapped as paludified areas.
- Silting water areas, flooded areas and rushes: The silting water areas are waters, that are turning to terrestrial habitats because of emergent vegetation or land rising. Flooded areas are regularly or part of the year covered by water. Rush symbols are points, which can be situated both on land and water. In water the symbol indicates aquatic vegetation above the water surface, and on land it indicates high rush or reed vegetation.
- Rocks and mineral soil (TopoRocks): The database consist of rocks; stony and sandy soil; jagged rocks; sand and gravel pits; and other mineral extraction areas. Rocks and mineral soil-database is used in the production of classes 3.3.1 and 3.3.2 together with IMAGE2000.

The so called BasicCD is a raster (2 m*2 m) version of topographic maps at 1:20 000 scale. It is used in the visual verification of CLC2000 and production peatland mask in northernmost Finland where TopoPeatland is not yet available.

3.2.3 Digital elevation model: The Elevation Model (DEM) is interpolated into 25x25 m grid using contour lines and coastline elements of the basic map 1:20 000 in National Land Survey (http://www.nls.fi/). DEM is used in ortho-rectification and topographic normalization of satellite images as well as in production of timberline.

3.2.4 Timberline: Timberline map was produced in order to deliniate the areas in northernmost Finland where the type of vegetation is mainly regulated by natural factors, not forest management. This was necessary in order to map naturally non-forested areas. Timberline map was generated by combining elevation surface with land cover data.

3.2.5 Peatland data for Northern Finland: Since the topographic database does not yet cover the northernmost Finland, peatland map (TopoPeatland) was extended to cover whole of Finland using topographic maps (BasicCD). Peatlands were first extracted automatically from topographic maps and checked visually on screen.

3.2.6 Vegetation zones: Satellite image interpretation is stratified according to vegetation zones in Finland (Working group… 2000). The strata is used also in the selection of representative coverage of field data in different parts of Finland, in the selection of pilot sites and in the mosaicing atmospherically corrected LANDSAT 7 ETM images. The delineation of strata is presented in Figure 2.

3.3 Field data

Forest and biotope maps of Metsähallitus and forest maps of UPM-Kymmene Ltd were used in the interpretation of vegetation type and coverage.

Forest maps are based on compartmentwise forest inventory for forest management purposes. Data collection is based on visual interpretation of false color aerial photographs and field measurements. Forest compartments are delineated on aerial photos and forest attributes are estimated in the field for each compartment. The size of forest compartments varies approximately between 0.5 – 20 hectares. This data is updated using growth models and completed forest management activities (e.g. cuttings) are recorded to the database regularly. Attribute data of forest maps include for example tree height, tree species proportions, age and timber volume. Since crown cover is not measured in the field, it is estimated using models build with field data measured in Swedish National Forest Inventory (Hagner 2003). These models are based on the measured forest characteristics like forest density (basal area), tree species proportion, age and mean diameter of trees.

In the northernmost Finland biotope maps produced by Metsähallitus were used as field data. The aim of biotope mapping is to describe the nature of area; biotopes, their state of nature, trees and other vegetation. Mapping has been performed as interpretation of 1:20 000 false-color aerial photographs using mirror stereoscopes. Also, some ground surveys have been done. The minimum mapping unit is 1 hectare (Eeronheimo 2000).

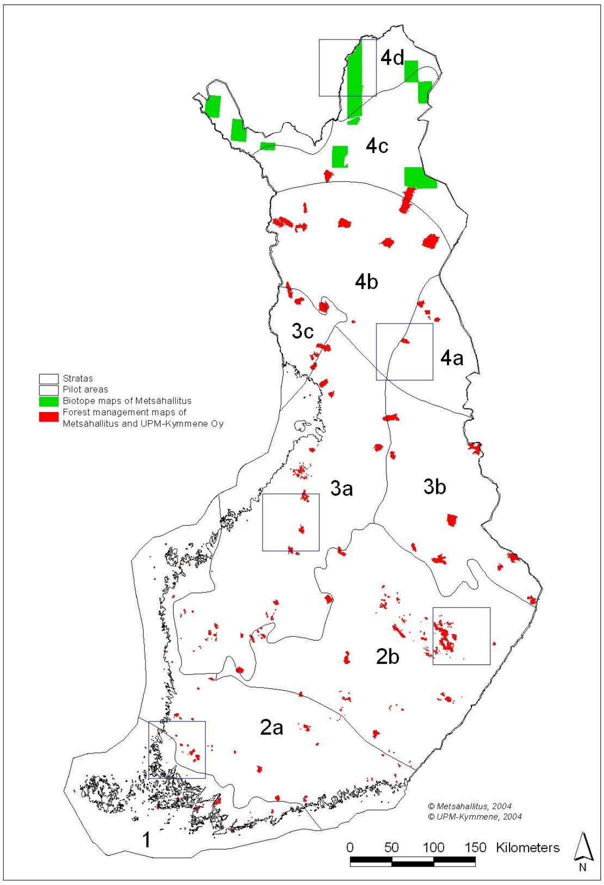

Figure 2. The strata, location of field data and pilot sites

Forest and biotope maps used in CLC2000 production is a subset (about 1 000 000 ha) of land managed by Metsähallitus and UPM Kymmene Ltd. Forest maps for CLC data were selected for each stratum separately. The aim was to select geographically representative sample for each strata and concentrate field data on the overlapping areas of satellite images. Location of field data is presented in figure 2. Field data is divided into two sets: training data and reference data for verification purposes.

3.4 Interpretation method

Automated satellite image interpretation was used in the estimation of vegetation type and coverage, and semi-automated approach was used in updating of map data and in mapping of coastal and inland marshes.

3.4.1 Estimation method: The estimation of continuous variables is performed using PROBA-software developed by Technical Research Center of Finland. The main parts of the estimation process are (Häme et.al., 2001):

- Image clustering was carried out using an unsupervised clustering method called k-means algorithm. The samples are selected from image by selecting spectrally homogeneous 2x2 pixel groups and computing their mean values. The purpose of this selection is to decrease the amount of mixed pixels in estimation process.
- Computation of class statistics for each cluster. Samples far away from their nearest cluster mean vector were not included because it was thought that these samples do not represent well their clusters.
- The assignment of the ground data and the clusters is done by calculating the mean and standard deviation of the target variables for each cluster.
- Estimation of continuous variables for whole image is done by searching the n nearest clusters for image pixel and giving the pixel value according to the weighted mean of these nearest cluster values. This weighting is based on the probability which the pixel belongs to different clusters.

3.4.3 Estimation of land cover variables: The original objective was to perform classification separately for each strata defined according to vegetation zones and additionally within each strata separately for peatlands and mineral soils. In practice this was not always possible due to problems with image calibration and seasonal differences between images within strata. For each strata separate set of field measurements was used in the estimation.

In order to produce CORINE classes in forests and semi-natural areas as well as in wetlands following land cover variables were estimated: tree height (m), tree crown cover (%), volume of broadleaved trees (m3/ha) and total volume (m3/ha). Additionally in northern Finland (strata 4d, 4c, 4b and 4a) ground vegetation type and coverage were estimated in non-forested areas.
Following characteristics describe the classification process:

- Blue band was not used in the interpretation because of significant atmospheric disturbances which were left in the images after calibration.
- Cluster statistics were calculated using image data covering the field data polygons i.e. forest/habitat compartments measured in the field.
- Number of clusters was set to 60-70 in mineral soils and 40-50 in peatlands depending on the amount of field data available in the strata.
- Both mineral soils and peatlands were classified two times in each strata. After first estimation field observations whose estimated tree height differed unexpectedly from measured value were excluded from the final estimation. This was necessary in order to find significant errors in the field data which were mainly due to forest clear cuttings not yet updated into field database or timing difference with satellite and field data. Unexpected height difference was set 2-3 times RMSE of height estimation in the strata.
- Estimates of total volume and volume of broadleaved trees in the strata were compared and calibrated with corresponding results of 8th National Forest Inventory in Finland (Tomppo et.al. 1998).

Estimation procedure was modified in Lapland (strata 4a-4d) due to different training data and lack of existing map data on peatlands.

- Estimation was not stratified according to soil type
- In addition of land cover variables describing tree cover also variables describing soil and ground cover vegetation type and coverage were interpreted.
- Ground cover coverage was interpreted using NDVI mosaic over Finland.

All separate, calibrated LANDSAT full scenes and homogenous image mosaics were classified. The final version of estimate was selected according to accuracy statistics and visually on screen where the aim was to generate seamless coverage of land cover estimates for whole of Finland. Selected stratumwise or imagewise classifications were mosaiced together for each land cover variable in order to produces nationwide data sets.

Continuous land cover variables were transformed into discrete CORINE classes by thresholding these variables according to class descriptions in CORINE nomenclature (Heymann et.al. , 1994, Bossard et.al., 2000).

3.4.4 Semi-automated interpretation: Semi-automated interpretation of Landsat ETM-images was used to update map data and in the mapping of wetlands.

3.4.4.1 Updating SLICES: Since SLICES-data correspond to the year 1999-2000 and does not always correspond the situation when IMAGE2000 images were received, some artificial surface -classes in SLICES land use element were updated. Urban fabric and industrial, commercial and transport units were updated using the Building and Dwelling Register corresponding to the year 2001. Large construction sites and golf courses were digitized on screen using Image2000. Peat exploration sites, dump sites and mineral extraction sites were updated using semi-automated interpretation of IMAGE2000. Additionally mineral extraction sites in parts of Finland were updated using areas digitized by the Regional Environment Centres from aerial photographs.

Updating was based on thresholding of LANDSAT band relation 7/4 and NDVI. Interpreted enlargements of artificial surfaces were combined with existing map data. At first peaty areas and bare land were extracted from these mosaics by level slicing separately from both mosaics. Also new areas of peat production areas were mapped. Updated areas were checked visually with the aid of IMAGE2000, map data (BasicCD) and aerial photos..

3.4.4.2 Coastal and inland marshes: Coastal and inland marshes were located using silting water areas, rushes, flooded areas and palustrines from the topographic database. The delineation of marshes was made using these map data together with interpreted potential vegetation in water and water bodies in SLICES land use element. Palustrines, that were adjacent to marshes, and had crown coverage less than 10 %, were added to marsh patterns. The produced marsh patterns went through a visual check-up and were completed with interpretation of IMAGE2000 if necessary.

3.4.4.3 Peatbogs: Peatbogs were mapped using peatlands and palustrines from the topographic database and completed with interpreted crown cover in forests. Open mires and peat exploitation areas were directly classified as peatbogs as well as peatland forests where the tree crown cover is under 10 %. Also palustrines adjacent to peatbog patterns with forest crown cover under 10 % were added to peatbogs.

3.4.4.4. Water bodies: Water bodies were mapped using thresholding approach with selected bands (1, 4, 5) in calibrated IMAGE2000 mosaic over Finland together with DEM. Possible but uncertain water bodies according to satellite data and water courses were extracted together with SLICES land use data. Water bodies were labelled into water courses, inland and marine waters using TopoWaters.

3.5 Data integration

Updated SLICES data, classified land cover data, TopoRock and wetland-data are combined into a single database. Priority list is made according to accuracy, importance and age of the data.
The priority list for data integration is:
1. Wetlands
2. Water bodies
3. Artificial surfaces
4. Agricultural land
5. Beaches, dunes, sand plains and bare rock
6. Forests and semi-natural areas

3.6 Generalization

Finnish CORINE2000 data is first produced as a raster data with pixel size 25 by 25 meters in the ground. For European use data has to be in vector format with minimum mapping unit of 25 hectars. An automated generalization procedure has been developed in order to produce required vector data from 25 meter raster data. The procedure is based on Arc/Info raster and vector operations and has following phases:
- Simplification of the input data
- Elimination of narrow linear features (roads, rivers) and single pixels
- Aggregation of the parcels to reach 25 ha inside each level 1 CORINE class
- Dissolving remaining small parcels to the most appropriate neighboring area according to the priority list
- Smoothing the boundaries of the parcels
- Merging working units (80 km by 80 km with buffer zone of 10 km) to one single nationwide database
- Vectorizing the raster database and final checks

During the generalization process heterogeneous classes are produced (class 243) or increased (class 313). A modified set of generalization rules were applied in strata 4c and 4d.

4. RESULTS

Validation of results is divided into internal validation which is based on separate set of field data, and external validation performed by European Topic Centre of Terrestrial Environment (ETC-TE) and Finnish Forest Research Institute (METLA).

4.1 Products

The output of Finnish CLC2000 project consists of calibrated IMAGE2000 mosaic and separated data layers on land cover, land use and soil. Specific outputs are produced by thresholding continuous land cover variables and data integration of separated layers according to user needs. The first produced data combination is the national CORINE2000 land cover database. Secondly it is generalized and vectorized into CORINE2000 data compatible with European standards

4.2. Internal validation

Land cover variables produced via automated satellite image interpretation were validated internally by the project team using forest and biotope maps as reference. A subset of field data was excluded from satellite image interpretation and used in validation. Estimates for polygons (n=2808) of field data were calculated as mean value of pixelwise interpretation results. Accuracy statistics is presented in table 2.

	RMSE	RMSE-%	BIAS	BIAS-%	r^2
Crown cover , %	12.4	33.0	-3.7	-9.8	0.64
Tree height, m	3.2	33.0	-0.7	-7.3	0.63
Volume of broadleaved trees, m3/ha	15.9	120.0	3.4	25.3	0.20
Total volume, m3/ha	41.6	45.8	-3.5	-3.9	0.65

Table 2. n, RMSE, $\bar{y}_{est}$, RMSE-%, BIAS, BIAS-% and r^2 of estimated land cover variables

4.3. External validation

The 1st external validation was completed by the technical team of ETC-TE in summer 2003 and the final validation will take place summer 2004. The objective of these missions is to harmonize CORINE data within Europe (vector data with mmu 25 hectars) according to CORINE standards. Additionally Finnish Forest Research Institute will analyze both national and CORINE2000 data using field sample plots of 9th National Forest Inventory.

In the first validation mission 22 units (10 km by 10km) were checked by ETC-TE technical team. The validation is based mainly on visual evaluation with the aid of satellite data and all available ancillary data sets. All verification units were accepted by the technical team and they concluded that the Finnish CLC2000 database (generalized version) is good; the results are very much similar to what could have been achieved by visual photointerpretation (Büttner et.al. 2003).

5. CONCLUSIONS

The objectives of CLC2000 project in Finland included firstly production of CLC2000 database, secondly production of data also for national use for diverse endusers and thirfly development of methods and tools for image calibration and land cover mapping for various purposes. According to the first validation results these objectives have been reached. Utilization of non-standard, automated data production approach together with exploitation of existing digital map data was proved to be successful in Finnish conditions.

Emphasis was put to the calibration of satellite images, whose aim was to reduce the amount of field observations needed for image interpretation and produce seamless, calibrated satellite image mosaic for various purposes and enable more reliable change detection. According to the experiences gained in the project so far image calibration and interpretation of image mosaics were one of the most challenging tasks in the project. Developed and applied image calibration needs further development to be fully operative.

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