

Mapping Land Use Changes for the Kyoto Reporting

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Abstract – The Kyoto reporting to the United Nations Framework Convention on Climate Change (UNFCCC) contain a comparison of the land use in 1990, 2005 and 2008-2012 that is needed to identify the land use changes and to calculate the possible carbon stock changes. To perform the reporting to the UNFCCC reliable and accurate information about the land area and area changes is therefore critically important for developing inventories. This paper describes the efforts to develop a method to fulfill these requirements in Denmark.

Keywords: Farmer data, Remote sensing, GIS, Kyoto Protocol, Climate Change, emission

1. INTRODUCTION

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) has been in force since 16 February 2005 and commits its Parties to limit net emissions of six major greenhouse gases during the period 2008-2012. For the commitment period 2008-2012, Denmark has committed itself to a reduction of the GHG emissions of 21% with respect to the 1990 reference year during the commitment period 2008-2012.

As far as CO₂ is concerned, the Protocol opens up for offsetting gas emission reduction by sink of carbon in carbon stocks. The Protocol explicitly obliges the parties to account for carbon sink related to afforestation, reforestation and deforestation activities under article 3.3. Article 3.4 of the Kyoto protocol opens for the possibility to include CO₂ sinks in forests, cropland and grassland as a consequence of changes in management. Denmark has selected Forest Management, Cropland management and Grassland Management as activities under Article 3.4.

These obligations all require detailed and verifiable information on land use and transitions between land uses, i.e. establishment of a full land use matrix for each reporting year. As a result, there is a need at the national level for routines and services that can provide nation-wide monitoring of the complete land use matrix since 1990.

There is thus an increasing need for accurate land cover information as land cover mapping is required to meet political commitments such as the Kyoto Protocol. Earth observation (EO) from space can provide consistent, accurate and timely information on land cover and land cover changes. Satellite imagery efficiently provides information on relatively vast areas, and is therefore a useful tool for land cover mapping; neither aerial photography nor field data can provide equal amounts of information as efficiently.

1.1 SATMON project

In Denmark a project, SATMON, was initiated to provide the required data for the Kyoto reporting. The project is being

managed by KU-LIFE at the University of Copenhagen and with participation of members from University of Aarhus.

The objective for this project is to derive land cover and land use change from 1990-2012 for the whole of Denmark in support of the Danish reporting to the Kyoto Protocol based on satellite imagery. The first step is thus to interpret satellite imagery and produce a land cover mapping for the years 1990, 2005 and later on 2012. The second step is to further classify these land cover maps into land use maps.

The ultimate goal of the work is to derive changes in land use throughout the period 2008 to 2012 with 1990 as reference year and to develop a land use change matrix which again will be the basis for emission estimates in the period 1990-2012.

The work with satellite imagery is however cumbersome as remotely sensed data are unstructured records of relative reflectance of particular wavelengths of electromagnetic radiation. A lot of interpretive work goes into extracting useful information from these images. By using appropriate methodologies, national land-cover classifications combined with current satellite imagery can be developed to useful source of land cover and land cover change information.

To 'convert' land cover to land use estimates the national GSE-FM land-cover classification from 1990 and 2005 is therefore combined with the available ancillary land use information from vector boundaries of wetland, crop land and open land nature etc... The identified areas are then compared to the classification unit of the satellite images and manually delineated.

The project is still ongoing so this paper will only cover the initial work of setting up a methodology for the mapping.

2. MAPPING METHODOLOGY

The general requirement for the mapping is described in details in (Intergovernmental Panel on Climate Change, 2003) and the use of Remote Sensing is described in GOF-GOLD, 2008).

The first element to establish was the classification scheme. The land cover classification scheme for this mapping effort was designed to be comparable to the standardised and hierarchical classification scheme used for the GMES-FM, CORINE and JRC land cover products.

The classification scheme is mainly based on the 6 land use classes to be reported in the Kyoto Protocol: Crop land, forest land, grass land, wet land, other land and settlement and in addition a class for water.

The Kyoto categories with subcategories are shown in table A. To be used operational these classes need to be adapted to the available other mapping data in Denmark as described in sec. 1.1.

Table A. Land use classes

Category	Subcategories (briefly described)	Definitions (short)
Crop-land	Annual crops, hedges, grass in rotation, fodder, fruit trees/orchards	Where cultivation cycles (fertilisation, ploughing, etc.) are performed.
Grass-land	Permanent grassland over more than 20 years, wet meadows, pasture land, managed grassland, designated from the field blocks,	Grassland which is not considered as cropland
Forest land	Forest according to the FAO definition	Area of more than 0.5 ha and minimum 20 m width etc.
Wet-land	Only peat extraction areas (managed); plus re-established wetlands	Covered or saturated by water for all or part of the year
Settlement	Build-up areas etc.	All development land
Other land	Rocks, water, lakes, dunes	Unmanaged

2.1 Available data

There are several data sources available for the mapping; both satellite imagery and ancillary data, i.e. Orthophotos, NFI (National Forest Inventory), Land Parcel Identification System (LPIS) or the field block map of Denmark, topographic vector data (Top10DK), nature protected areas (§3), wetland restoration areas, Summerhouse areas and Forest reserve areas.

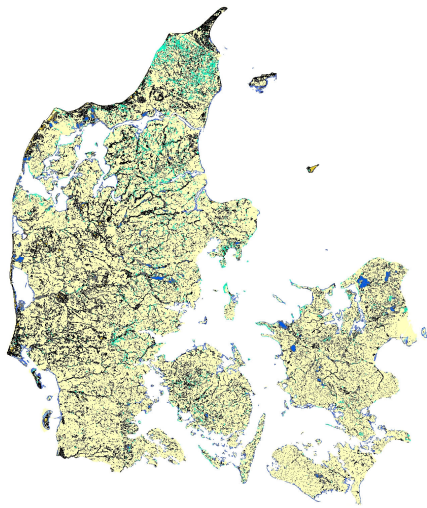


Fig.4. §3 areas (in yellow the areas not covered by §3)

Many of these vector layers from the ancillary data fit into only one of the above classes, which will help the classification work a lot. But a number of the land areas could fit into several classes. One of these is the GLR data, which relate to the field block map. And in many cases the vector layers are overlapping, which confuses the classification.

2.2 GLR data

The GLR data represent the “agricultural land” as declared by farmers applying for subsidy. Since 1996 the farmers annually declare their single parcels by drawing them on orthophoto maps within unique blocks on yearly basis. The blocks are well defined and linked to the UTM 32 coordinate system and contain generally between 1 and 10 single field with an average of 3.5 fields per block. The block map was initially updated on annually basis, but from 2008 it is updated on daily basis.

The digital block map from 2005 consisted of over 332.000 blocks and 3.000.000 ha “agricultural land”. The claims from the farmers summed up to about 2.800.000 ha. About 63.000 of these blocks didn’t contain any claims from the farmers and a large number of the remaining blocks were not fully claimed by the farmers.

Fig. 1 shows the block map (agricultural land) in Denmark in 2005. The farmers could declare a number of different crop types divided into several subsidy groups with different amount of subsidy per ha. For the purpose of use in the SATMON project and the SATMON LU map the single crop types were regrouped to fit one of the six SATMON classes. Using the crop code table the 2005 claims were divided into the SATMON LU classes: Cropland, Forest, Grassland, Urban, Wetland and Other.

Table 1 Distribution of claimed crops per parcel into the six SATMON classes.

Class	Parcels (pcl)	Claimed area (ha)	Avg. (ha)	Area %	Pcl %
Cropland	696,051	2,680,970	3.85	95.7	92.4
Forest	16,970	38,336	2.26	1.4	2.3
Grassland	35,954	74,325	2.07	2.65	4.77
Other	3,857	7,012	1.82	0.25	0.51
Urban	204	260	1.27	0.01	0.03
Wetlands	53	167	3.15	0.01	0.01
Total	753,089	2,801,069	3.72	100	100

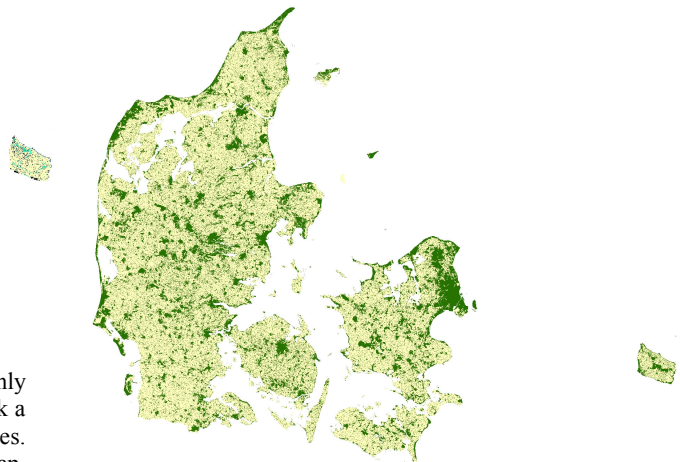


Fig.1. Block map 2005 (blocks in yellow, other land in green)

Since the single blocks could contain in average 3 single fields and in some cases up to 15-20 single parcels, a single block could contain a variation of single classes or up to six mixed classes.

Table 2 Distribution of classes per block

Class	Blocks	Area (ha)	Avg. (ha)	Area %	Block %
Cropland	231,657	2,453,137	10.6	79	70
Forest	3,248	8,875	2.7	0	1
Grassland	8,343	34,310	4.1	1	3
Other	378	1,277	3.4	0	0
Urban	36	43	1.2	0	0
Wetlands	10	38	3.8	0	0
Mixed	25,782	497,501	19.3	16	8
No claim	62,836	118,729	1.9	4	19
Total	332,290	3,113,911	9.4	100	100

As seen from table 1 all six classes were declared by farmers in 2005. Cropland is the far most frequent. The claims can be divided into the blocks and the major part of the single blocks only contains one SATMON class. This can be seen from table 2, which also shows that 62.836 blocks are not containing any claims and that 25.782 blocks are containing more than one SATMON class each (Mixed classes).

Most of the mixed classes are only containing two SATMON classes, which can be seen from table 3. Most of the mixed classes with only two SATMON classes are containing Cropland and Grassland. Table 2 also shows that the blocks with no claims only count for 4% of the total block area, meaning that 96% or a little less than 3.000.000 ha block area contains the 2.801.069 claimed area. So consequently a large proportion of the blocks are not fully claimed.

3. TEST OF GLR DATA

3.1 Development of a methodology

The test was done on a mapping for the GSE (GMES Services Element) Forest Monitoring (GSE-FM) from 2005. In this mapping all areas within the field block map were generally allocated to the Cropland class.

Before starting the methodology work a number of requirements to the identified erroneous parts were drafted. DJF made some tests to develop the methodology to be used in the total mapping with these initial requirements:

- The main purpose of this mapping was to highlight the areas, where GSE-FM map according to the farmer claims was wrong.
- The mapping should give precise location of the wrongly classified pixels in the GSE-FM map.
- These two limitations of the mapping plus the fact that all blocks with nature types (§3) should not be mapped in this phase determined the methodology.
- Furthermore a limited project budget only allows the major errors in the GSE-FM map to be corrected.
- Last but not least any changes to the GSE-FM map should be easy to implement.

3.2 Choice of test area

It was initially decided that only blocks with the single classes and the mixed classes with only two SATMON classes. On basis of the above analysis DJF started to develop a methodology to identify the erroneous parts of the GSE-FM map that needed updating. Aabenraa commune was selected as test area.

The area of Aabenraa commune is about 942 km² or a little more than 2% of the total area of Denmark. There were 8089 blocks with their centroid in the commune. The commune consisted of 6605 of the blocks with a single SATMON class and some 479 with mixed classes and about 1000 blocks without claims in 2005.

3.3 Final methodology

An initial method was developed to fit with the requirements. The method consisted of a number of database selections and GIS analyses to avoid the smaller possible errors to be selected for manual checking.

After having a look at a sample of the initial selected erroneous blocks in the Aabenraa area for budget reasons it was decided to change the initial criteria a little, so only larger blocks and larger errors were selected. It was also decided that only single class blocks were analyzed. See flowchart in figure 1.

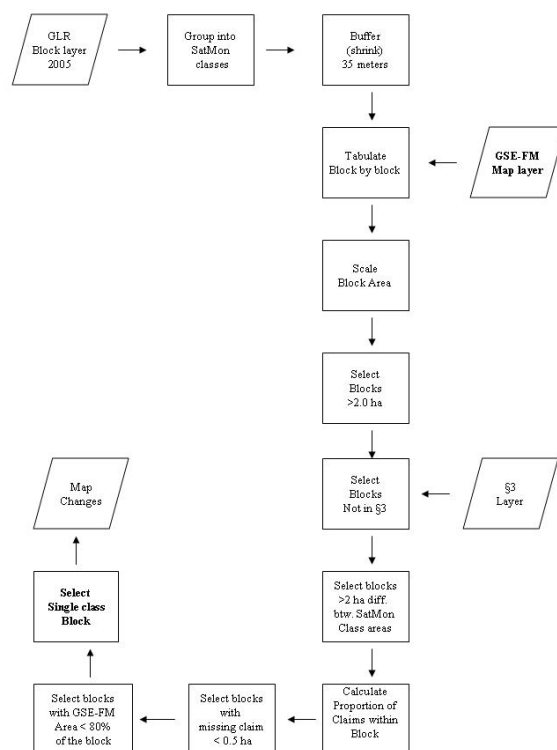


Figure1. Final methodology for the test

The “tabulation” tool in the ArcGIS programme was used to count the single SATMON LU pixels within the blocks. After initially visual check of a number of the blocks it was decided to create a

35 m buffer inside the block polygons, in order to reduce noise from the neighboring blocks and areas. Furthermore at first hand it was analyzed whether the §3 nature type map could be used to help mapping the mixed classes, before finally deciding that all blocks crossed by the §3 nature types were excluded from the sample. After applying the buffer 6107 single class blocks remained.

The initial exercises showed that 456 out of 6107 blocks were selected as erroneous in Aabenraa commune. This meant that about 20.000 blocks should be checked at national level, if the initial methodology was used and extrapolated the result to national level. This was not possible for budget constraints to check all of these blocks visually, so an adjusted methodology was introduced.

This means that we select from all blocks buffered 35m and without nature types, the blocks that have:

- 1) Block area larger than 2 ha
- 2) A difference between the tabulated area from the GSE-FM map and the claimed area > 2ha
- 3) That the claimed area of the SATMON class at least covers 80% of the block area
- 4) That the proportion of the tabulated area of the SATMON class is < 80% of the tabulated area for the block.

All these potential errors were photo-interpreted with both ortho-photo and satellite imagery background. This work was supplemented with a quality check of the photo-interpretation by an independent operator.

The result of this selection was that for the single class blocks we found the following errors:

	Blocks	Block area (ha)	GSE-FM map (ha)	Claims (ha)
Cropland	743	5.996	1795	5.793
Grassland	467	2.298	5	2.217
Forest	239	1.197	148	1.157
Settlements	4	12	0	12
Other	6	21	0	21
Wetland	0	0	0	0
Total	1459	9.524	1.948	9.200

Table 7 Proportion of the SATMON classes within the buffered blocks

The distribution of the quality checked blocks where errors occur in the GSE-FM map is shown in table 8.

	Blocks	erroneous	%
Cropland	721	563	78%
Grassland	63	54	81%
Forest	49	46	94%
Settlements	4	1	25%
Other	0	0	n/a
Wetland	0	0	n/a
Total	837	664	79%

Table 8 Distribution of the final erroneous blocks

Some of the errors found were only partially wrong or more than one wrong class was found within the block. In these cases it is

not possible to allocate a unique class to the block in question. Of course this reduces the number of block corrections that could be found compared to the figures in table 8. On the other hand some blocks were 100% wrong which could be used as corrections for the class that was found using GLR. Finally 552 blocks were selected as the erroneous blocks to be corrected in the initial map as shown in table 9.

	Correction
Cropland	488
Grassland	54
Forest	8
Settlements	2
Other	0
Wetland	0
Total	552

Table 9 Number of proposed corrections to the GSE-FM map

Compared to the initial more than 300.000 blocks 552 erroneous blocks seem very little. But one has to take into account that only larger errors and larger blocks were visually checked. If all minor errors should have been fixed, the photo-interpretation work might have lasted for many years. So the adapted methodology in these analyses has to be changed if the mapping has to be made for another year. Recommendations for this work will be developed under another work package.

4. CONCLUSIONS

There is a need for accurate Land use information for the Kyoto reporting. All states that have committed itself to the Kyoto Protocol face a large job to gather this information and make it consistent. The work done in Denmark so far has resulted in a methodology development that will help to create the required LU maps for 1990, 2005 and 2008-12. Furthermore a number of recommendations have been described and will be used for the further mapping and reporting work.

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