EUROPEAN FORUM FOR GEOSTATISTICS

VEGETATION CHANGE DETECTION FOR STATISTICAL INSTITUTES

A CASE STUDY FOR COMBINING BUILDING REGISTER DATA WITH SATELLITE IMAGERY

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VEGETATION CHANGE DETECTION FOR STATISTICAL INSTITUTES

ABSTRACT

The extensive development in and around the major cities has increased the pressure on green spaces in urban environments. Improved building and population registers, land use data and satellite imagery can result in a better understanding of the changes and where they occur in relation to the location of the population.

Most of the partners within GEOSTAT 1B project are privileged to have georeferenced registers and have therefore little need to disaggregate data for generating population on 1x 1 km grids. However, a similar approach combining various sources as satellite imagery, land use and building register data can be used when assessing the vegetation changes in and around urban areas.

The reason why this is of such an interest now is that from 2015 it will be possible to supplement information from map databases and registers with satellite observation data from the European satellite Sentinel -2. In order to be prepared for data from the Sentinel -2 satellite this study will test how this approach can function using Moderate Resolution Imaging Spectroradiometer (MODIS). MODIS geographical resolution is of 250 meters, but the temporal resolution (the frequency of observations) is comparable.

The objective of the case study was to combine building register data, land use data and satellite imagery in order to follow changes in vegetation caused by construction and land use change. The results are promising and even with low resolution it was possible to follow changes in vegetation in various land use categories. Large scale construction works were also possible to detect, but with imagery with better resolution will make this approach even more relevant. However, the stepwise methodology is applicable and promising for the years to come.

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Background

The extensive development in and around the major cities has increased the pressure on green spaces in urban environments. Improved building and population registers, land use data and satellite imagery can result in a better understanding of the changes and where they occur in relation to the location of the population.

Most of the partners within GEOSTAT 1B project are privileged to have georeferenced registers and have therefore little need to disaggregate data for generating population on $1km^2$ grids. However, a similar approach combining various sources as satellite imagery, land use and building register data can be used when assessing the vegetation changes in and around urban areas.

The reason why this is of such an interest now is that from 2015 it will be possible to supplement information from map databases and registers with satellite observation data from the European satellite Sentinel -2. In order to be prepared for data from the Sentinel -2 satellite this study will test how this approach can function using Moderate Resolution Imaging Spectroradiometer (MODIS). MODIS geographical resolution is of 250 meters, but the temporal resolution (the frequency of observations) is comparable.

The objectives of this study are to:

To use satellite images to follow actual changes in vegetation in combination with reported construction works (according to building register). Develop a method that is generic and can be used by any National Statistical Institute having access to:

- a building register (including date of construction starts),
- areas of interests (in the case of Norway green urban areas and forests, urban area delineation and water bodies),
- Satellite imagery with high temporal coverage.

Methodology

Building register

The building register of Statistics Norway is a part of the Norwegian Cadastre. Statistics Norway does some quality enhancements of this register based on data from comparable registers.

This register was used for obtaining data about the construction start and the various buildings ground floor area.

Areas of interest

In this study we focused mainly on green areas and forest areas in and outside urban areas. We chose here to use the data of the land use classification and the urban areas of Statistics Norway. We excluded all water bodies with an area larger than 10 % of each MODIS pixel in order to reduce distortion.

Imagery of interest

Being a country with a long coast line, mountains and a sea temperature considerable higher than the air temperature on mountainous land side have consequences on the weather. Large parts of the country have many days with a high degree of cloud coverage. This leads to that the number of cloud free days are very few and when choosing earth observation satellite it is therefore important with high frequency of observations.

In this pilot phase we chose to use Moderate Resolution Imaging Spectroradiometer (MODIS) as satellite that provide imagery with readymade vegetation index every 8 days (combining every 16 days observations of MODIS-Aqua and MODIS-Terra). This frequent earth observation will in a near future be accessible with a better geographical resolution (10x10 meters) in form of Sentinel 2[1]. Sentinel 2 will also allow the user to obtain imagery every 2nd-3rd day. This work can be seen as a preparatory work in front of Sentinel.

MODIS Vegetation Indices 16-Day L3 Global 250m (MOD13Q1) are designed to provide consistent spatial and temporal comparisons of vegetation conditions. Global MOD13Q1 data are provided every 16 days at 250-meter spatial resolution in the Sinusoidal projection. MOD13Q1 is a gridded level-3 product that means that it is radiometrically corrected and resampled using geolocation information[2]. The MODIS geolocation is (± 50 m (1σ) at nadir) due to improved models of the spacecraft and instrument orientation in the MODIS geolocation software since the launch[3].

The vegetation index used for this assignment is the Enhanced Vegetation Index (EVI) of MODIS that minimizes canopy background variations and maintains sensitivity over dense vegetation conditions. More importantly, for this assignment the EVI also uses the blue band to remove residual atmosphere contamination caused by smoke and sub-pixel thin cloud clouds. This distinguishes it from the more commonly used Normalized Difference Vegetation Index (NDVI). In the case of MOD13Q1 both vegetation indices are computed from atmospherically corrected bi-directional surface reflectance that have been masked for water, clouds, heavy aerosols, and cloud shadows[4].

Vegetation period

Once the data is defined it is appropriate to define the period over year that is of interest. This is appropriate to define in an early stage of the project in order to limit the data to download and process. In the case of southern Norway this period was set to be the period from mid-April to the end of October. In Julian days (365 days) this means approximately from day 100 until day 300.

The municipality of Drammen

Drammen city lies 40 km south west from Oslo and is one of the fastest expanding urban areas in Norway. In October 2013 the population of Drammen was 64 597 and made it to the ninth most populated city in Norway. The increase in population results also in a pressure on land use and it was therefore found to be an appropriate city to be used in a case study.

[1] ESA, 2013 http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2

[2] https://lpdaac.usgs.gov/products/modis_products_table/mod13q1

[3] http://modis.gsfc.nasa.gov/sci_team/pubs/abstract.php?id=03385

[4] http://www.ctahr.hawaii.edu/grem/mod13ug/sect0005.html

Process

This work started with defining an appropriate portal for downloading a large number of images. MODIS data is today accessible via various portals and the one used in this project was Earth Explorer (https://lpdaac.usgs.gov/data_access/usgs_earthexplorer).

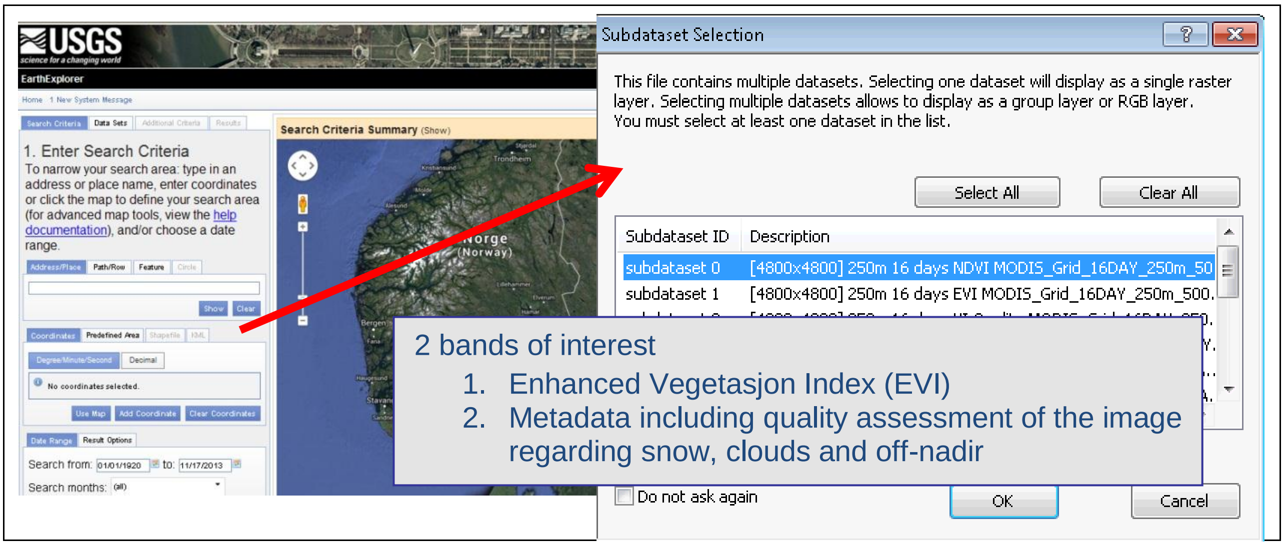


Figure 1/Step 1 in the data handling process is to access and define the data of interest on the EarthExplorer utility:

1. Search for Geographical area of interest: *e.g. "Southern Norway "*
2. Search for vegetation indices (250x250m) MOD13Q1 (Terra) and MYD13Q1 (Aqua)
3. Define Dates of interest: *e.g. Vegetation period for "Southern Norway", Julian day 100-300*

On the right is an overview of the subdata selection utility in ArcGIS in order to select the bands of interest. This process was automated using Model builder and Python using functionalities in ArcMAP.

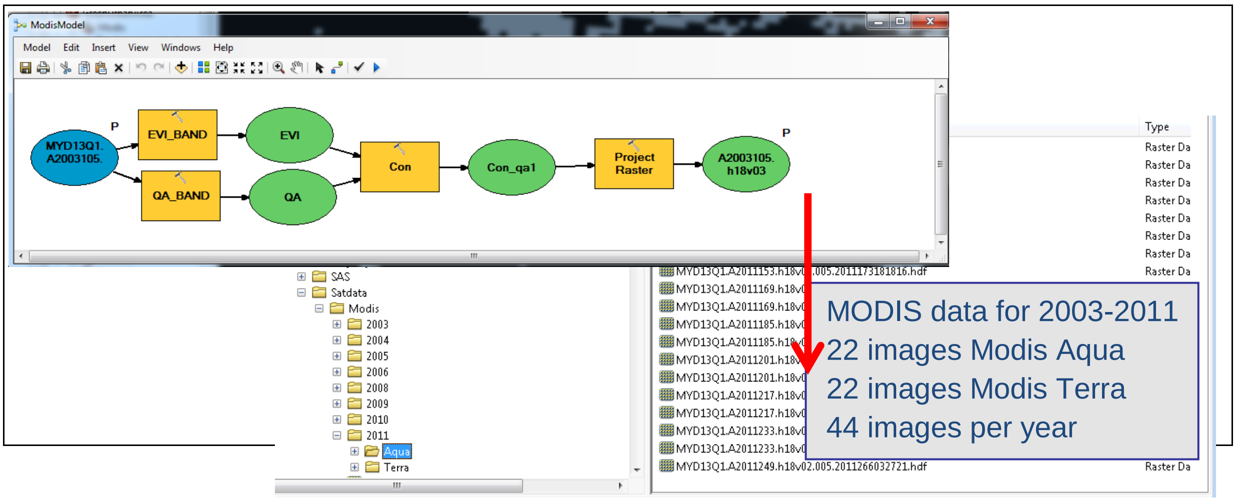


Figure 2/Step 2: Automating the selection of bands as well as setting a condition for keeping all

image data with so called reliable pixels according to the data provider (USGS). For more information about MODLAND see MODIS Vegetation Indices (MOD13) C5 User's Guide http://www.ctahr.hawaii.edu/grem/mod13ug/sect0005.html.

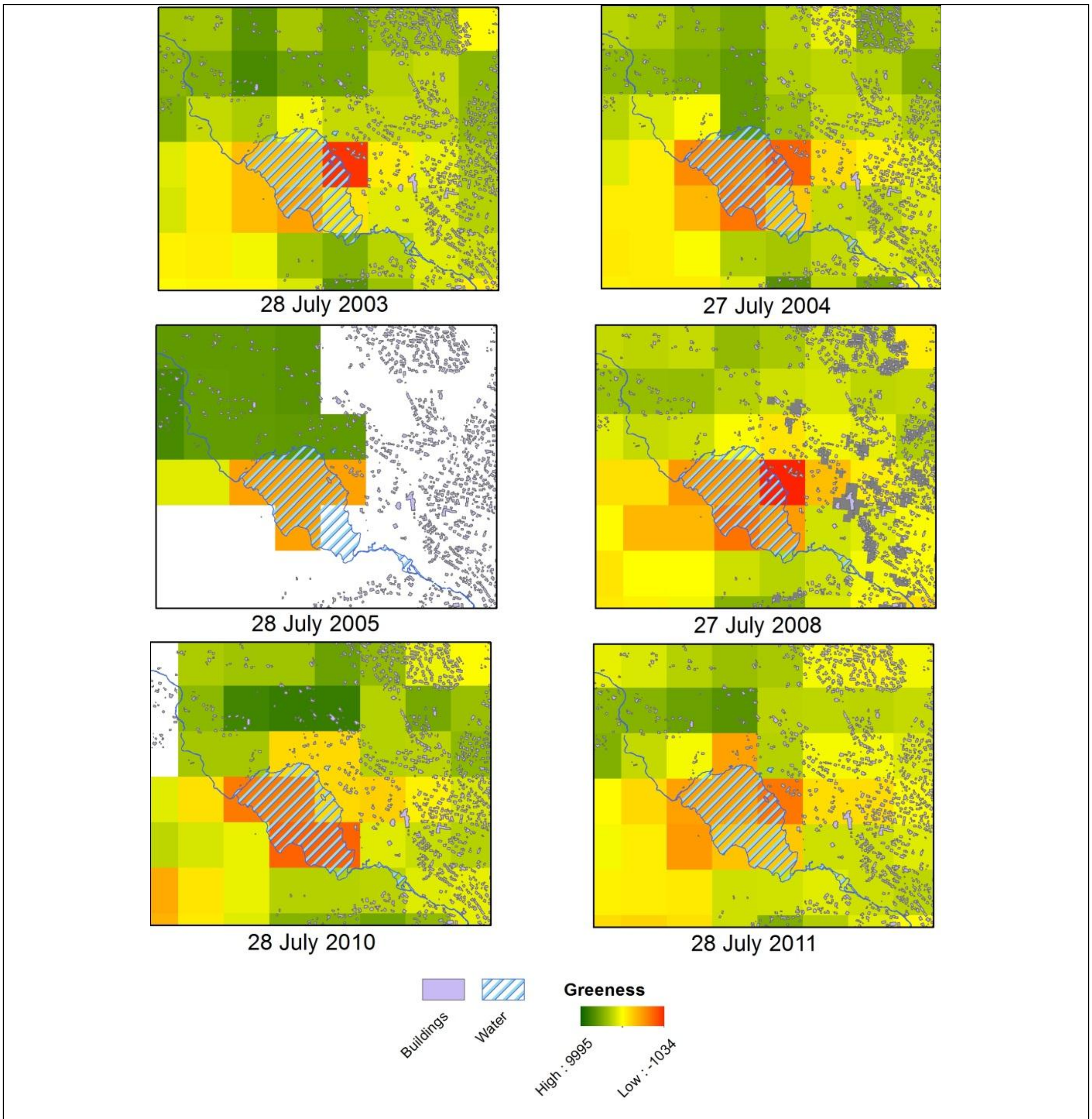
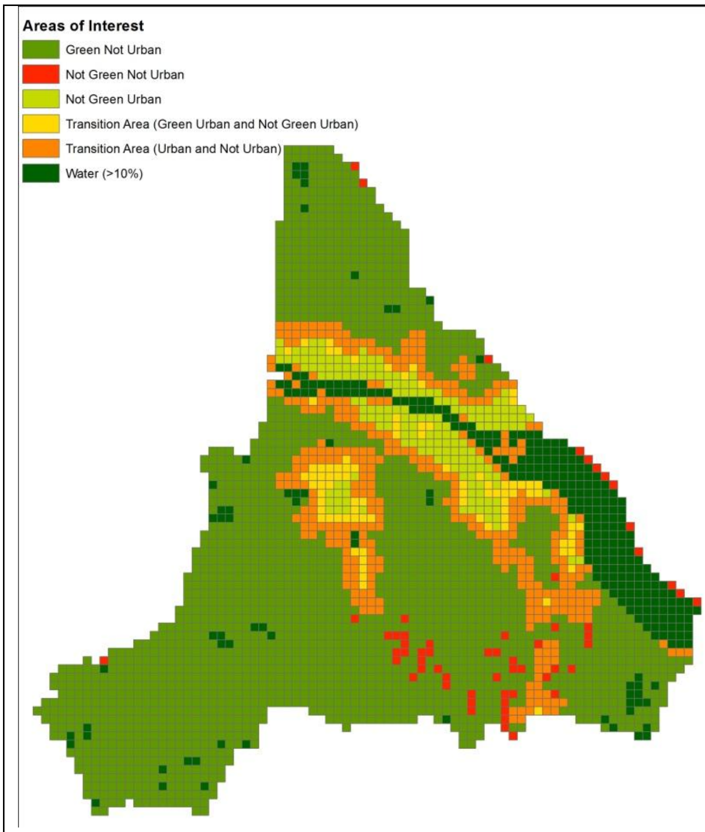


Figure 3/Step 3: Ground Control Points. Having in mind that the MODIS dataset is global and that the resolution is coarse, some reference locations were chosen to be verified before processing the data. Valid control points were here water bodies and sealed soils due to buildings or roads. In figure 3 above is an example of a control area where the water body has a constant low greeneess value compare to the surroundings. The conclusion is that the accuracy of the data makes pixel-to-pixel comparisons over time difficult and it was therefore in this project found appropriate to:

- Masking out pixels with more than 10 percent covered by water
- That the level of detail of the areas of interest (AoI) was operable
- Correlate the vegetation index of the AoI with typical green forest areas outside urban areas (not or hardly affected by human activity in the period 2003-2011) = EVI_{dif}

$$EVI(AOI_n) - EVI(Not\ Green\ Not\ Urban) = EVI_{diff}(AOI_n)$$

- Calculating the EVI_{diff} an average over the year




```
count=0
for fc in fcs:
    print fc
    n = datetime.datetime.now()
    print n
    fc_substr = fc[0:10] + "_" + fc[12:17]
    #fc = "V:\\Satdata\\Modis\\2008\\MOD2008113.h18v03.img"
    # Lokale variabler
    #

    if count == 0:

        print count
        print fc_substr

        # 3a.Processer
        #
        # Process: Clip
        arcpy.Clip_management(fc, "#", ws + "clip.img", path + "\\KommuneClip" + Kommune, "", "NONE")

        # Process: Raster to Point
        arcpy.RasterToPoint_conversion(ws + "clip.img", path + "\\clip_point", "Value")


        print count
        desc = arcpy.Describe(ws + "clip.img")
        #print(fc)
        Number_of_Columns = desc.height
        Number_of_Rows = desc.width
        CellHeight = float(desc.meanCellHeight)
        CellWidth = float(desc.meanCellWidth)
        ExtentXMin = float(desc.Extent.xmin)
        ExtentYMin = float(desc.Extent.ymin)
        ExtentXMax = float(desc.Extent.xmax)
        ExtentYMax = float(desc.Extent.ymax)


        # Process: Create Fishnet
        arcpy.CreateFishnet_management(path + "\\Fishnet_" + Kommune + "_" + Aar, str(ExtentXMin) + " "

        # Process: Spatial join
        arcpy.SpatialJoin_analysis(path + "\\Fishnet_" + Kommune + "_" + Aar, path + "\\clip_point", pat
        arcpy.AddField_management(path + "\\Fishnet_" + Kommune + "_" + Aar + "_" + str(count), fc[0:10]
        arcpy.CalculateField_management(path + "\\Fishnet_" + Kommune + "_" + Aar + "_" + str(count), fc
        arcpy.DeleteField_management(path + "\\Fishnet_" + Kommune + "_" + Aar + "_" + str(count), ["POI

        n2 = datetime.datetime.now()
        print n2


    count +=1

    # 3b.Processer
    #
    # Process: Clip
    arcpy.Clip_management(fc, "#", ws + "clip.img", path + "\\KommuneClip" + Kommune, "", "NONE")
```

Figure 4/Step 4: GRID production, once the AOI (find the categories in the legend to the map) were defined the work with generating grids started using numerous images. The MODIS images were converted into grids using the "CreateFishnet function" in combination "Raster to points function" in ArcGIS. This enabled us to generate yearly grids for the period 2003-2011 including attributes every 8 days in the vegetation period.

The yearly EVI grids were thereafter combined with AOI and building data. There are some overlaps in between the categories and a hierarchical structure was therefore defined. This structure was in reverse order to the legend in figure 4 starting off with "Green Not Urban" areas as a baseline and adding the various categories on top finishing off with the water mask.

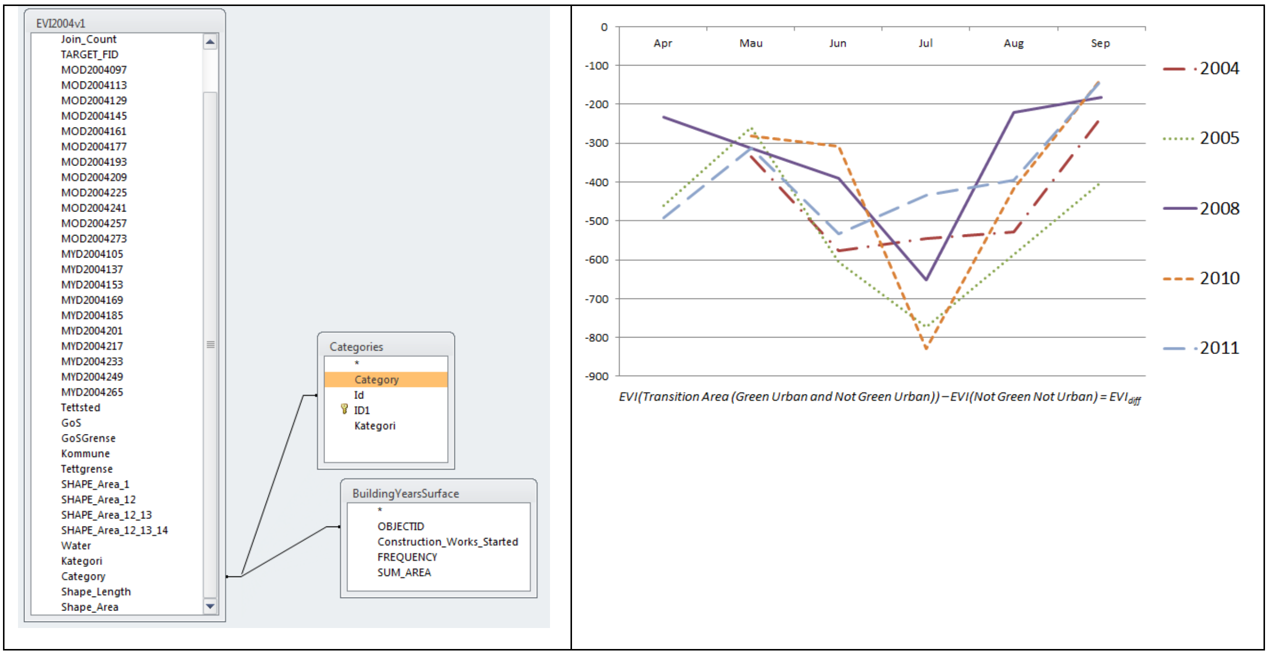


Figure 5/Step 5: Calculating the EVI_{diff} and generating statistics. Using the grid format for combining imagery data for various dates, AOI categories and building data make database work and use of statistical software easy. The GRID-ID enables us to combine a wide range of data and to do comparisons over time of the $EVI_{diff.}$

Results and conclusions

Satellite imagery with frequent observations provides a big amount of data that needs to be organized in such a way that it can be used in combination with other sources of information. In this project we focused on generating overall vegetation statistics for different areas of interest as well as monitoring the effect on vegetation caused by construction works in the following areas of interest:

1. Green areas include the following land use categories: forest areas, parks, cemetries, amusement parks, fête grounds and other meeting places as well as other not classified green areas[5].
2. Urban areas excluding the land use classes under point 1.
3. Transition areas in urban sones between green areas and not green areas.
4. Transition areas in between urban and rural areas.

Since the grid was generated based on the MODIS imagery the resolution is the same (250 m) and this resulted in that there were no green areas in Drammen that covered a whole grid cell. Nevertheless, about 3 % of the grid cells were so called transition areas or boardering grid cells areas in between green and not green urban areas. Another transition area was the boarder areas in between urban and rural areas.

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[5] http://www4.ssb.no/stabas/ItemsFrames.asp?ID=8372002&Language=en&VersionLevel=classversion&MenuChoice=Language

Table 1. Statistics over the various areas of interest covering the municipality of Drammen

Areas of Interest	Grid cells	Percentage
Green Not Urban	2189	68 %
Green Urban		
Not Green Not Urban	72	2 %
Not Green Urban	178	5 %
Transition Area (Green Urban and Not Green Urban)	89	3 %
Transition Area (Urban and Not Urban)	392	12 %
Water bodies	318	10 %
Total	3238	100 %

The vegetation index for the green-/rural areas proved to be more or less constant over the period 2003 and 2011, as illustrated in chart 1. As stated under step 3 this category was therefore used as a benchmark for correlating the EVI of the other AOIs.

Chart 1. The EVI for green not urban areas in Drammen Municipality, 2003-2011

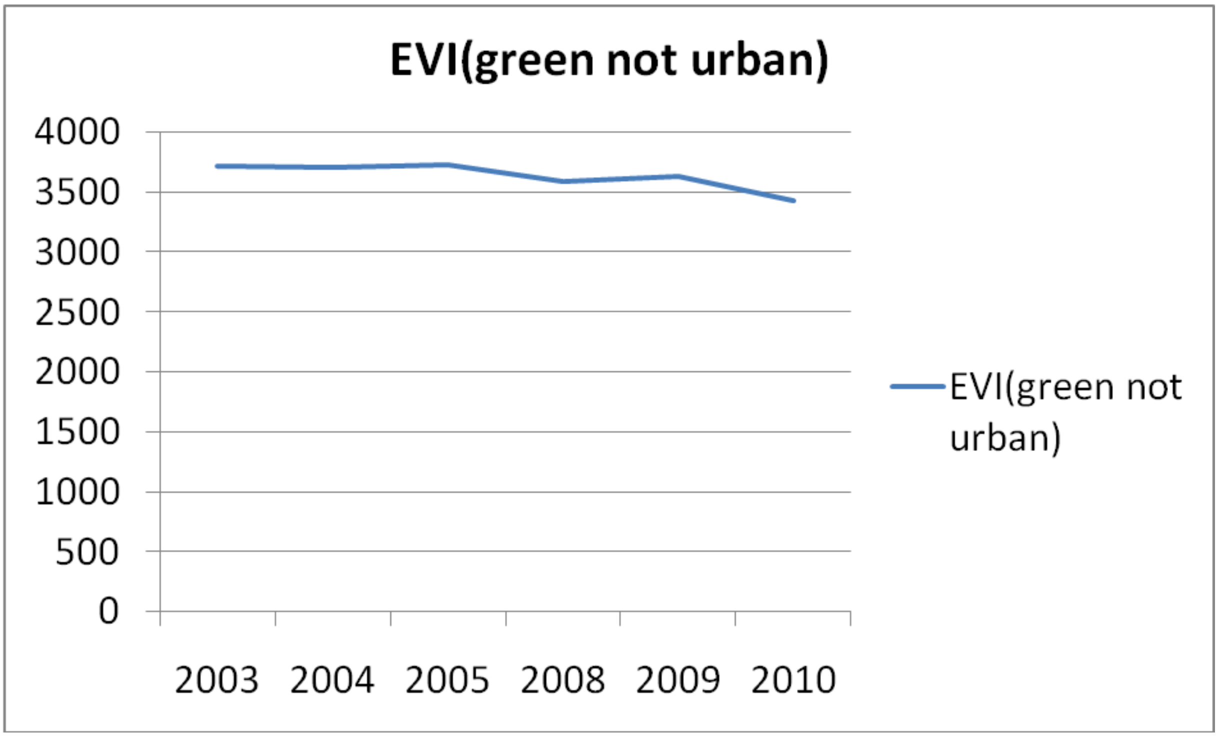
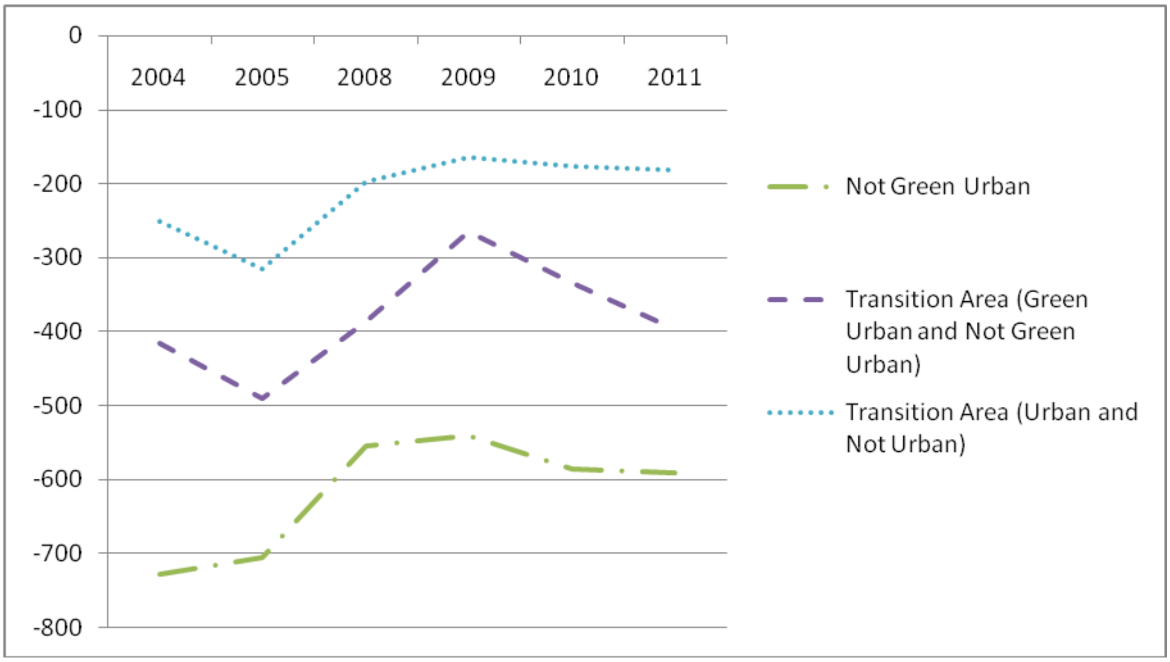


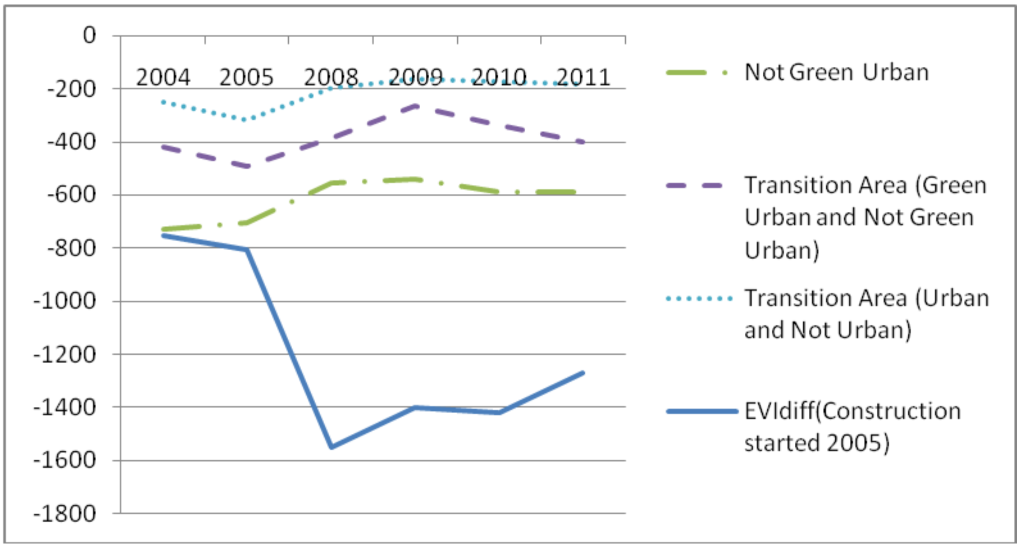
Chart 2 below illustrates that the difference in greenness (EVI_{diff}) in between “green not urban areas” (EVI = 0) and the various categories in urban areas. The difference has become smaller as a result of the slight reduction of the EVI for green not urban areas (chart 1) as well as an increase in greenness for the AOIs in chart 2.

Chart 2. The EVI_{diff} for various AOIs in Drammen Municipality, 2003-2011



In order to test the effects of construction works we selected the construction started in 2005. This means a series of affected pixels. Even though MODIS with low resolution it is only possible to detect larger construction works, but in this case the change in EVI is evident. In chart 3 it is possible to see the direct decrease in vegetation due to the construction works and the following increase that is probably a result of that the areas surrounding the building become greener.

Chart 3. The EVI_{diff} for various AOIs as well as the EVI_{diff} for grid cells including buildings built in 2005



Conclusion:

This methodology proved to be operable for combining satellite imagery with register data. With modifications this can become a powerful approach to handle a large number of satellite images. Combining this data sources can allow updated building register and land use data. Transforming the data into grids make also the data more manageable for statistical institutes who are more used to work with statistics software than remote sensing software.

Sources:

MODIS Land Team Validation, 2011, http://landval.gsfc.nasa.gov/ProductStatus.php?ProductID=MOD13

Dallimer Martin et al., 2011, Temporal changes in greenspace in a highly urbanized region. (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3169039/)

Didan Kamel et al., 2006 MODIS Vegetation Index Product Series Collection 5 Change Summary (https://lpdaac.usgs.gov/sites/default/files/public/files/MOD13_VI_C5_Changes_Document_06_28_06.pdf)

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Johansen B. E., 2009, Vegetasjonskart for Norge basert på Landsat TM/ETM+ data http://www.norut.no/alta/Norut-Tromsoe/Publikasjoner/Rapporter/Vegetasjonskart-for-Norge-basert-paa-Landsat-TM-ETM-data

Thorén, K. H. et al., 2010. Kartlegging av urban grønnstruktur med satellittdata. Kart og Plan 70(4), pp. 238-253.

http://publications.nr.no/5526/Thor_n_-_Kartlegging_av_urban_gr_nnstruktur_med_satellittda.pdf