

LANDSAT TM DATA FOR DOCUMENTATION AND SIMULATION OF LANDSCAPE CHANGE IN SWEDEN

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ABSTRACT

Extensive structural changes are in progress in the Swedish landscape and for landscape planning purposes methods for documentation and simulation of landscape change are required. The aim of this preliminary work is to develop a model that can be used to simulate different landscape scenarios. This model is supposed to assist evaluation of the effects of various alternatives. A framework based on digital classification of LANDSAT TM data was developed. The data were manipulated to simulate changes and the hypothetical scenarios were discussed with reference to vegetation, animal and human requirements.

Key words: Landscape change, LANDSAT TM, simulation.

1. INTRODUCTION

Governmental proposals and subsequent parliamentary resolutions as response to European agricultural policy will bring change to the Swedish landscape. During a ten year period approximately 20% of the area under cultivation will be excluded from high yielding production to reduce a surplus of agricultural products. An environmental goal is included in the resolution, where a rich and complex agricultural landscape is to be preserved and environmental pollution by agricultural production to be minimised. The conversion is directed by economic support and economic help is provided for farmers who adapt to the new policy.

We are facing an enormous structural change of the Swedish landscape if the goal of 20% less arable land at the year 2000 is to be reached and it will cause both ecological and visual change. This is an opportunity as well as a threat.

No decisions have been taken to guide farmers as to which fields to 'abandon' and actions must be preceded by numerous considerations. Each area has an economic value for the owner, an ecological value for the region and a value as a visual landscape. With the specified environmental goal in mind each decision must create opportunities for preservation or development of a rich and complex environment.

The chances to create something of considerable value depend on the possibilities and abilities to make forecasts and also on the possibilities to exert influence on decision-makers. The mission for landscape ecologists is to provide information about effects and to give recommendations in specified regions.

The aim of this preliminary study is to develop a model that can be used to simulate different landscape scenarios. The purpose of the model is to assist recommendations concerning various landscape-change alternatives.

2. BACKGROUND

Several articles have been written about deforestation and habitat fragmentation is, according to many authors, the most serious threat to biological diversity (Wilcox and Murphy, 1985). A forest consists of edge and interior core. Species have different requirements; some prefer edge conditions, some core conditions.

Deforestation creates new patterns; edge length in an area may increase or even decrease but the amount of interior core is always reduced (Zipperer, 1989). In order to describe patches and to estimate proportions between edge and core different methods have been used. A simple area (A) to perimeter (P) ratio can describe patch form. The quota reveals where the patch lies on a scale where maximum is given by calculating the A/P ratio for a disc with the same area. Minimum is given by $A/(A \times 2 + 2)$, which holds for areas without islands. Even fractal dimensions have been used to characterise landscape patches. Here the fractal dimension could be described as the relationship between a quantity (Q), and the length scale (L) over which Q is measured. Hence the relationship between area and patch length could be described as $A = \beta L^{D_a}$ and the relationship between perimeter and patch length as $P = \tau L^{D_p}$. From this we can derive a relationship between area and perimeter as $A = \beta (P/\tau)^{(D_a/D_p)}$ (Milne, 1991).

The A/P ratio and fractal dimension are insensitive to differences in patch morphology; i. e. areas with the same A/P ratio can have different form and be of quite different ecological value (LaGro, 1991). With spatial contiguity and clustering data these problems are in part overcome and the data provide useful information on boundary configuration as well as intra-patch pixel clustering (LaGro, 1991). In order to restore habitats they could provide useful information.

What has been mentioned above concerning deforestation is to a great extent applicable to reforestation and new plantation. If minor areas are chosen for tree planting their localisation will be of great importance. Possibilities of connecting 'islands' has to be considered as well as edge effects. Different species have different needs and different ways of dispersal. It is important to start with an ecological network analysis in each area of interest.

The use of remote sensing as a tool for analyses of environmental and natural resource characteristics is documented and the potential of LANDSAT and SPOT data for identification of various landscape elements have been studied by Dufourmont, 1991, Goossens et al., 1991, LaGro, 1991, Sader et al., 1991 f.x. Information concerning structural landscape parameters were extracted from SPOT imagery by Dufourmont et al., (1991). The applicability of SPOT data for spatial planning and landscape ecology was illustrated through two case studies. Fisher, (1991) improved an algorithm based on digital elevation models (DEMs) for the establishment of view shed. LaGro, (1991) interpreted aerial photographs in order to acquire land-cover data in central New York State. The obtained land cover maps were manually digitised and the classified digital images were applied for characterising the shapes of grid-cell patches by quantifying the spatial contiguity and clustering of the pixels within each aggregation or patch. The author found contiguity and clustering data to be useful for landscape planning and management decision-making, as layers in a geographic information system. The potential of satellite data for detection of ecological structures and patterns in Belgium was studied by Goossens et al., (1991). Edge-enhanced SPOT images were used for identification of field patterns and associated linear elements. The potential of satellite data was analysed in relation to the size and the shape of land blocks and the kinds of linear elements bordering the land blocks. The use of edge-enhanced SPOT images for ecological network analysis was studied as well. Conclusions were that SPOT imagery mapping of ecological infrastructure can produce maps, which can supply information for further ecological work. Sader et al., (1991) studied LANDSAT-TM data for analysis of migratory bird habitats in Costa Rica. The authors conclude that satellite data have the potential of giving information concerning habitat availability and habitat conservation that cannot not be acquired by means of other sources.

3. STUDY AREA

The study was performed in the province of Scania in Southern Sweden. The province is dominated by agriculture, although large areas with higher elevation are mainly covered with forests.

Rapid structural change is expected where fields are sparse and low yielding. In those areas average acreage per farm is typically low and farmers usually own both agricultural land and woodlots. The most economic alternative may be tree planting for energy or timber production, but then large areas may lose their character entirely.

The study site covers an area 5 x 5 km corresponding to the cadastral map sheet 3C2f (1:10 000). The test area is situated north west of Kågeröd in a region where structural change is most likely to take place during the years to come. It serves as an example of a production landscape found on and nearby ridges in Scania. Crop agricultural land and forests areas occupies equal parts.

4. MATERIAL, METHODS AND ANALYSIS APPROACH

4.1 Material and methods

Two types of data were used in this study; agricultural statistics and digital satellite data.

4.1.1 Agricultural statistics

Once a year all agriculture units larger than 2 ha report their acreage and specified land use to the Central Bureau of Statistics (SCB) in order to keep agricultural statistics up to date. These data are supplemented with records of applications for subsidies. Two ways of application are possible; one specifying acreage taken out of intense production and the other specifying acreage and new land use. Positions are not specified by the farmers. In this study records of total agriculture acreage, total of previous subsidy area, total of applied subsidy area, specified new land use and adherent acreage are used.

The figures below refer to those properties that are totally or to some extent situated within the study area. In the register of previous (1990) subsidy applications the subsidy area is 1400 ha. This concerns 51 properties with a total area of 1770 ha. Most of the land categorised as agricultural area has been used for production entitled to subsidies. The area of new applications (1991) for subsidies amount to 380 ha but new land use has been specified for less than 10% of this area. Of the 51 agriculture properties present in the study area, 49 had registered subsidy area. 15 land owners applied for new subsidies but only 4 had specified new land use. This ought to be compared with the figures for the administrative province of Malmö (= county) covering half of Scania, where 19% of approximately 6800 land owners applied for subsidies and 5% had specified new land use. The study is based on applications registered up to autumn 1991.

4.1.2 Digital satellite data

In order to be able to use up to date data and to make fast analyses digital satellite data were used as 'base maps'. Satellite data were LANDSAT-5 TM acquisitions from the 9th of June 1988 and from the 16th of July 1988 (path/row 194/21). Absolutely calibrated digital values (DN) on CCT were transformed to spectral radiance (mW/cm²sr_{um}) (Markham and Barker, 1985). Multitemporal data were corrected with relevance to between-scene variability caused by (i) solar irradiance differences and (ii) atmospheric

influence (Scarpace et al., 1979, Markham and Barker, 1985, Lo et al., 1986). Radiometrically calibrated images were geometrically corrected by performing a resampling of one image to the cadastral map sheet 3C2f (1:10 000). The other image was then resampled image-to-image to the first. The resampling algorithm was nearest-neighbour and a DIPIX Aries III image analysis system was used. Through the resampling procedure pixel sizes were reduced to 25m.

Based on multitemporal LANDSAT TM data a land use classification was carried out. A classified image with five land use classes (raising linear vegetation elements, forests, arable land, pastures, water surfaces) were produced using the maximum-likelihood algorithm of the grid-based geographic analysis system IDRISI. During the classification stage and for evaluation of the classification result randomly selected areas were used to characterise the five land use classes considered. These areas were visited. In order to improve the accuracy of the classifier a post-classification clean-up filter was applied. Evaluation of the classification results showed Kappa accuracy's around 80%.

Pixels of the land use classification were transformed into mass pixels (raising linear vegetation elements, forests) and open space pixels (arable land, pastures, water surfaces). An image with only two categories of pixels was thus obtained.

4.2 Analysis approach

Starting from open space pixels the mean of the lengths of all search lines along their respective search directions before hitting a mass pixel was measured. The maximum search distance was set to 1400 m and the mean value is termed mean view length (MVL) (Dufourmont et al., 1991). Calculations of MVL were performed in IDRISI. IDRISI was also used for establishing the area and perimeter of each group of mass pixels and open space pixels. For each of these polygons the A/P-ratio was then calculated.

In this preliminary work different scenarios were built on knowledge about:

- which farms had applied for subsidies
- their position on map
- total acreage of arable land, total of previous subsidy area
- total acreage according to application
- in some cases new land use and adherent acreage and on assumptions about:
 - preferred locality out of different viewpoints
 - new land use - forest

Scenario 1: The farmer decides which fields he will exclude from agricultural production. He had economic reasons for his application. He wants to get rid of low producing fields - poor soil, steep hillsides - exposed to erosion, damp conditions - cold in spring, small and lobate fields. He wants to have his remnant fields near his farm-house in order to keep fuel costs low.

Scenario 2: The ecologist is interested in preservation, immigration and survival of different species. In Scania larger forests are located on the ridges. Forest fragments or woodlots often have a short history and are composed of few species - mainly Norway spruce - if planted. An opportunity

species - mainly Norway spruce - if planted. An opportunity to get larger forested areas is welcomed in particular when deciduous plants are chosen. In order to facilitate flows of individuals, propagules etc. he builds corridors that link remote 'islands'. These narrow zones are also important as shelter areas (to roe, deer).

A third scenario was supposed to be built on the assumption that 20% of all previous subsidy area was excluded from agricultural production but farmers in this area have applied for subsidies for a total of 380 ha which equals 27% of previous subsidy area.

It is assumed that fields taken out of agriculture production will be planted with trees. Thus these were added to the LANDSAT-scene as mass elements. MVL and the A/P-ratio were calculated for the original scene as well as for scenarios 1 and 2. Discussions were held about the scenarios out of three standpoints; the farmer, the ecologist and the visitor.

5. ALTERNATIVES OF CONVERSION

The initial scene with only two categories of pixels is given in Figure 1. Mass pixels (raising linear vegetation elements, forests, built-up areas) are shown in black. In the area no municipalities are present. The scene shows an area with some small isolated woodlots but also larger forest.

In scenario 1 approximately 270 ha land is converted from agricultural production into forest. We assume that most farmers will choose tree planting because of high profit. The size of the area has been reduced based on the proportion of each property within the test area. Farmers choose the most favourable location from their point of view. First low productive areas such as all fields with poor soil or with damp conditions are excluded, then small and lobate fields and those located on steep hillsides are chosen for conversion. In order to keep fuel costs low every farmer wants to have his fields centred around his farm-house. These assumptions constitute a base for the scene shown in Figure 2. Even if it wasn't the farmers wish to connect woodlots he has in the upper right corner built corridors that will probably facilitate species dispersal. In the left lower corner two previous forest islands have been connected thus creating raised survival conditions for present species. The visitor will notice that forested area has increased but the difference is small due to previous presence of isolated woodlots in the fields. Forests are often located near common roads. The alternating cultivated and forested hilltops creates a harmonious landscape.

In scenario 2 the ecologist is responsible for the location of new forest. As in the previous scenario 270 ha is converted. We assume that he favours possibilities to secure survival of different species and to facilitate their propagation and dispersal. As mentioned above forests composed of deciduous plants are desirable in this area. The loss of 'open space' may reduce the visual value but it may also have positive effects due to expanded patch interior conditions. A long time ago wild boars were roaming large beech forests. The growing population and expansion of agriculture pressed back the forests to the ridges, but when agriculture production methods changed areas with poor soil were

planted with conifers. Some woodlots are small and isolated. Squares and rectangulars, patterns normal in ordinary forestry, have large cores in proportion to edge but these 'islands' are too small to develop interior conditions. The ecologist locates his new plantations in order to connect these isolated woodlots (see upper left corner of Figure 3) in order to improve conditions for immigration etc.. He also favours plantations where he can get a varied humidity gradient. The situation in the left lower corner is the same as in scenario 1 due to property boundaries. The farmer dislikes remnant fields where parts have been covered with forests. The visitor has the same comments as above. The new scenario has created a somewhat more intimate and varied landscape.

Mean view-lengths (MVL), based on eight directions, were calculated for all open space pixels in the original scene as well as for scenarios 1 and 2. These values were classified and plots were made. At first sight the original scene looked very similar to the two scenarios. The plots are dominated by the highest MVL-class. This effect is possibly due to a maximum search distance of 1400m. Only pixels that have mass pixels quite near on three sides belong to other classes.

In scenario 1 added woodlots and corridors have cut off parts of the upper right corner and hence created a mixed landscape with shorter MVL.

In scenario 2 localisation of new woodlots has not caused any great change. The largest effect is to be found in the upper left corner where new plantations are screening of an 'agricultural bay'.

As a second approach mean view-length was calculated for all mass pixels and three plots were made. This gave some information about the interdependence of size and form that partly could be used in discussions about interior core conditions and habitat size. As expected narrow strips and

small 'islands' showed low values. But if corridors had a straight direction the length could compensate and raise the value to maximum.

The area and perimeter of each group of mass pixels and open space pixels were calculated. As outcome is dependent on grain no transformations to m^2 and m were made. For each of these polygons the A/P-ratio was calculated. The total edge length of present forest-polygons was also computed.

In the initial scene 16 forest-polygons were present. Their total edge length was 2722, as pixel size was 25 x 25 m this equals to 68,050 m. The edge length of each polygon varied between 500 and 15750 m. In scenario 1 the total edge length of 14 polygons was 3320 (=73,000 m) but in scenario 2 total edge length of 12 present forest polygons was lower, 3078 (=76,950 m). This is due to the ecologists wish, he has succeeded in creating large areas with interior core conditions.

The A/P-ratio was calculated for every polygon as well as maximum and minimum for each area. The quota reveals where the patch lies on a scale where maximum is given by calculating the A/P ratio for a disc with the same area. Minimum is given by $A/(A \times 2 + 2)$, which holds for areas without islands. Only one polygon lies near its maximum A/P ratio. The rest are spread around the mean.

Scenario 1 and 2 have affected different polygons in different ways, but often the A/P-ratio is lowered. Fractal dimensions will add more information to the picture. The area dimension ($1 < D_a < 2$) has been calculated for all forested polygons but the conclusions are still to be drawn.

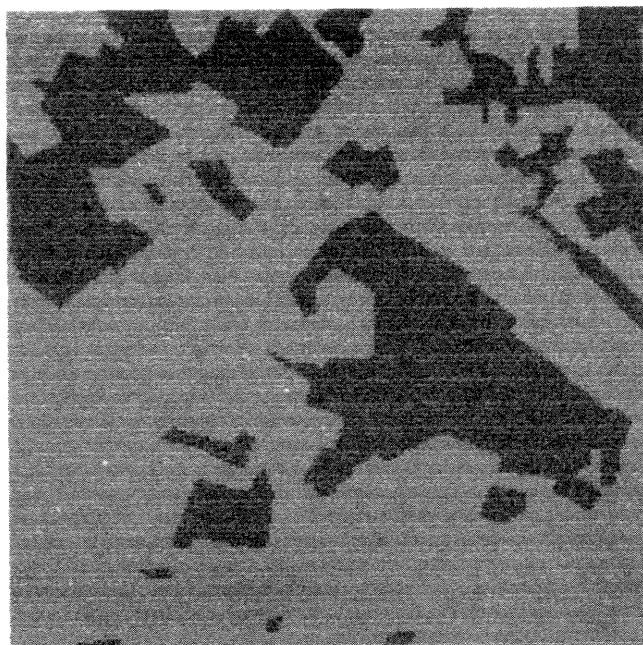


Figure 1. The initial scene with two categories of pixels. Mass pixels are shown in black and open space pixels are shown in grey.



Figure 2. Simulated landscape change - the farmers choice. Mass pixels are shown in black and open space pixels are shown in grey.

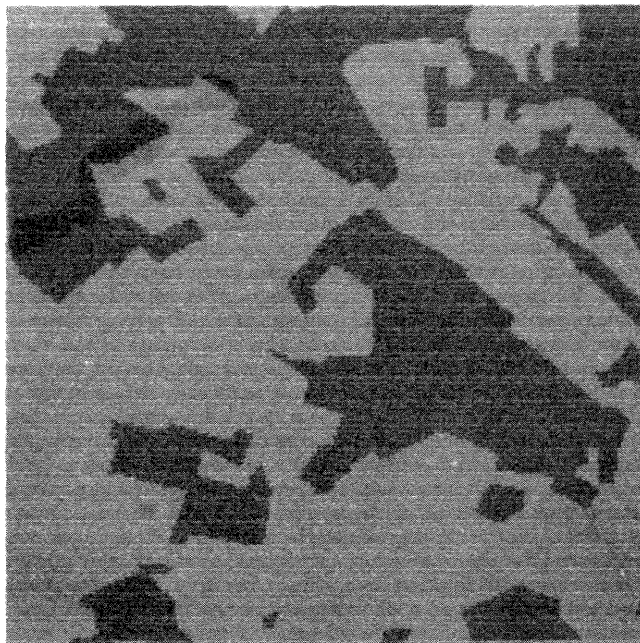


Figure 3. Simulated landscape change - the ecologists choice. Mass pixels are shown in black and open space pixels are shown in grey.

6. CONCLUSION

The environmental goal added to the parliamentary resolutions regarding the reduction of agricultural area is to preserve a rich and complex landscape and to minimise pollution by agricultural production. If this goal is to be fulfilled much beneficial information can be gained through simulating various landscape scenarios and evaluating the effects of various alternatives against each other.

This study shows that a digital land use classification of LANDSAT TM data can supply information fit for use when simulating hypothetical landscape changes. Based on the data, simple maps showing the distribution of mass pixels, open space pixels, mean view-length, area to perimeter ratio and fractal dimensions are easily created. These maps may constitute a foundation for further discussions among various persons (farmers, ecologists, planners, decision makers, the general public).

It must be stressed that the results and discussions presented in this paper are preliminary and will be complemented with further work.

REFERENCES

- Dufourmont, H., Andries, A., Gulinck, H., Wouters, P., 1991. A structural landscape analysis based on SPOT imagery. IALE-conference. May 2-4 1991, Roskilde, Denmark.
- Fisher, P., 1991. First Experiments in Viewshed Uncertainty: The Accuracy of the Viewshed Area. *Photogrammetric Engineering and Remote Sensing*, 57(10):1321-1327.
- Goossens, R., D'Haluin, E., Larnoe, G., 1991. Satellite image interpretation (SPOT) for the survey of the ecological infrastructure in a small scaled landscape (Kempenland, Belgium). *Landscape Ecology*, 5(3):175-182.
- LaGro, J., 1991. Assessing Patch Shape in Landscape Mosaics. *Photogrammetric Engineering and Remote Sensing*, 57(3):285-293.
- Lo, T., Scarpace, F., Lillesand, T., 1986. Use of multitemporal spectral profiles in agricultural land-cover classification. *Photogrammetric Engineering and Remote Sensing*, 52:534-544.
- Markham, B.L., Barker, J.L., 1985: Spectral characterization of the LANDSAT thematic mapper data. *International Journal of Remote Sensing*, 6:697-716.
- Milne, B., 1991. Heterogeneity as a multiscale characteristic of landscapes. In *Ecological Heterogeneity*, eds. J. Kolasa and S. Pickett. New York: Springer-Verlag.
- Scapace, F.L., Holqvist, K.W., Fisher, L.T., 1978. LANDSAT analysis of lake quality for statewide lake classification. *Proceedings of the 44th American Society of Photogrammetry*, 173-195.
- Sader, S., Powell, G., Rappole, J., 1991. Migratory bird habitat monitoring through remote sensing. *International Journal of Remote Sensing*, 12(3):363-372.
- Wilcox, B., Murphy, D., 1985. Conservation strategy: the effects of fragmentation on extinction. *American Naturalist*, 125:879-887.
- Zipperer, W., Burgess, R., Nyland, R., 1989. Interaction of lands use and forest island dynamics in central New York. *Proceedings of the 1988 Society of American Foresters National Convention, Rochester, New York, October 16-19. SAF Bethesda, Maryland*, pp. 137-140.