Landscape change monitoring in Alpine regions: decision making tools from remote sensing data for tourism development planning

Christian Huggel, Marcel Zurflueh & Dominic Brander
Computer Vision Group, Communication Technology Laboratory, ETH Zurich, Switzerland

Hans-Caspar Bodmer
Swiss Federal Institute for Forest, Snow and Landsacpe Research, Birmensdorf, Switzerland

ABSTRACT: In many Alpine regions tourism is a driving force in the environmental development and influences landscape in various ways. In two test site in the Swiss Alps with different tourism impact changes in landscape were analysed over a period of more than 100 years. Temporal sequences of aerial photographs were mosaicked and classified according to feature classes relevant to changes in landscape. An IRS-LISS image was classified likewise and additionally first tests with IKONOS data were carried out. For the period before 1940 historical maps were digitized. All data was introduced into a GIS where landscape changes were analysed specifically. The results showed a massive impact of tourism industry on landscape in one of the test sites. A main focus was thereby set on changes in forest cover and forest habit in relation to construction activities and in a last step to the tourists' preferences.

1 INTRODUCTION

For many mountainous regions tourism is a crucial component of the regional economy. Generating economic growth and enhancing the quality of local residents tourism can even be a major force for environmental 'good' in the sense of protection of specific nature reserves or cultural traditions. However, potentially there exists a paradox at the heart of major tourism developments: that tourism destroys or degrades environmental resources attracting tourists at the first place (Hunter & Green 1995). Especially alpine regions with sensitive ecological systems run the risk to loose their attraction when strong tourism development starts.

Landscape is thereby a key element in the supply - economically speaking - and, hence, the understanding of the interactions between tourism and landscape changes is of great importance. However, only few changes in the landscape are known in detail since human memory is surprisingly short-lived in this respect.

This study aims at evaluating how far high resolution remote sensing can contribute to the assessment of long-term changes in landscape in an alpine environment. Landscape changes are thereby viewed under a perspective of the relation to tourism development. For this purpose two test sites in the Swiss Alps were selected which represent different concepts of tourism promotion.

A crucial point to future tourism development is how tourism-related landscape changes affect the tourism itself. Recently perception studies have found correlations between a certain stage of landscape and the tourist's preference (Hunziker 1992). In this study a further step is undertaken to relate the changes in landscape observed in both test sites to the empirically-based preferences.

Landscape changes have been repeatedly assessed quantitatively by pattern analysis using specific indices (Li & Reynolds 1993, McGarigal & Marks 1994, Qi & Wu 1996) including indices derived from aerial photography (Turner 1990, Falencka-Jablonska et al. 2000). Statistical correlation between landscape patterns and scenic beauty suggests that complexity and diversity are driving forces in landscape preference (Kaplan et al. 1989, Hunziker & Kienast 1999).

The present study was carried out within the frame of the interdisciplinary EU-project CARTESIAN (Aerts et al. 2000).

2 TEST AREA AND DATA

For the present study two test sites were selected having undergone contrasting ways of tourism development. Crans, the first area (20.8 km^2), is located at the northern slope of the main Rhone valley in the Valais, Switzerland, and stretches from about 900 to 1800 m.a.s.l. It has experienced a major tourism impact affecting heavily the appearance of the area from landscape changes to ecologically- and socially-related alterations. Winter tourism is actually the main source of profit and ski industry takes a dominant position. Crans hosted major international ski sport events such as the Alpine Ski World Championships in 1987.

In the Goms valley (14.5 km^2, 1300 to 1900 m.a.s.l., upper Rhone valley), on the other hand, impact of tourism has been much less dramatic. The area shows few changes with respect to tourism infrastructure or settlement growth in the last 100 years. Tourism demand for winter and summer season is approximately in balance. In winter tourism activities concentrate mainly on cross-country skiing and alpine ski infrastructure is virtually missing. In contrary to Crans, the Goms area has never shown any intense increase in tourism such that, for instance, the number of spent nights in accomodation facilities or population in general have evidenced only minor fluctuations.

Monitoring landscape changes induces a multitemporal concept which was carried out using multitemporal remote sensing data over a period of nearly 60 years (1941 to 1998). A set of the oldest available aerial photographs (1941 and 1946, respectively for both test sites) was acquired, however, the quality is somewhat reduced and physical photograph size smaller than of today's standard cameras. A three time-stepped approach was chosen with corresponding panchromatic aerial photographs from 1946, 1969 and 1998 for Crans and 1941, 1967 and 1994 for the Goms valley. The end of the 1960ies was considered as an important period in tourism development and was therefore selected as the middle time step. Space-borne remote sensing data entered the study with an IRS-LISS image of 1997. This actually empowers the study to come up with methodological comparisons, i.e. aerial photographs versus high resolution satellite imagery. Additionally, a test data set of IKONOS (Pan and MS) could be aquired within CARTESIAN but the data is unfortunately located somewhat outside the test sites.

As no official aerial photographs were taken before the Second World War, the period from the end of the 19th century until 1930 (three time steps) had to be covered by historical maps ('Siegfried' maps).

Supplementary information was obtained from statistical data related to tourism such as the number of accomodation facilities and, finally, terrestrial photographs enabling the visualization of landscape changes over large time periods (around 100 years) were collected and taken.

3 LANDSCAPE CHANGE DETECTION METHOD

The main task was to convert the different images and maps into GIS-conform information layers. The images available from aerial photography and satellite aquisitions were analysed with respect to certain feature classes (forest, meadow, rock/bare ground, settlement). The maps had to be digitized according to the same features.

In order to compare such images change detection is a frequently used method in remote sensing. Methodological approaches range from visual comparison to automatic image analysis of remote sensing data taken at two or more different times. In this study a multi-dimensional approach was followed (Fig. 3). The objective of investigating landscape changes over the last 100 years made the additional inclusion of non-remote sensing data necessary (i.e. Siegfried maps). However, in terms of data information and degree of abstraction topographic maps, especially old ones, do not compare with remote sensing data such as aerial photographs and satellite images. Methodologically, both data sources had therefore to be handled separately to achieve consistent trends.

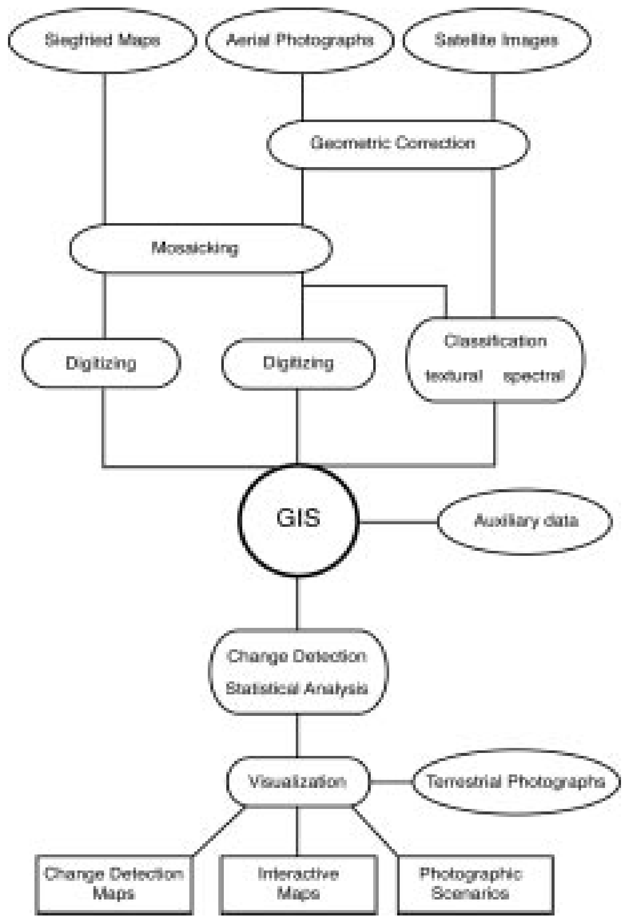

Figure 1. Applied method flow.

Both aerial photographs and satellite images had to be corrected geometrically. Up to 22 aerial photographs were then joined to form an orthorectified mosaic for each time step and test site. In addition to the geometric distortions, radiometric differences caused by sun angle-dependent shadows and variations during film development (e.g. brightness) had to be handled to create a seamless mosaic. An automatic mosaic algorithm was applied for the mosaicking process. Still, it is known that the automation of mosaic algorithms, for instance the seamline selection, suffers from several limitations (Afek and Brand 1998). This implicated partly a reduced overall quality of the mosaics, less regarding geometric aspects but more in terms of radiometry posing a problem to the subsequent automatic classification.

The next step included digitizing and classification of the orthorectified mosaics and the satellite images. The above-mentioned land cover classes (forest, meadow, rock/bare ground, settlement) were defined. These features were considered to represent the most relevant changes in landscape and could technically be extracted from the used remote sensing data. Extended shadow areas in the aerial photographs required specific treatment.

For the aerial photographs first an unsupervised classification was applied to evaluate the potential of the defined classification features. Owing to the mentioned limitations of the mosaics and the non-uniform appearance of a single feature class in a panchromatic photograph a spectrally-based classification alone did not provide satisfying results. The main classification was therefore carried out by a texture-based algorithm using Angular Second Moment, Entropy, Contrast, Correlation and Mean as textural features (Conners and Harlow 1980). In some areas the classification problems could still not be overcome completely. Selected features such as roads or buildings which were difficult to extract automatically were mapped by digitalization.

As outlined above the old topographic maps (Siegfried maps) were handled separately. After scanning the maps were mosaicked for both test areas. Considerable geometric distortions of the original maps became obvious during the process. A similar feature scheme was then applied while digitizing the map mosaic.

The IRS-LISS image was classified by a supervised maximum likelihood algorithm using the same feature classes as in the case of the aerial photgraphs.

All classification results entered into a GIS database. Additionally, auxiliary data such as statistical and tourism-related data was introduced into the GIS. Aiming at the detection of changes in landscape the analysis and comparison of the characteristics of landscape features at different times was based on GIS specific operations. In consideration of the complexity and interaction of the processes active in a landscape such a method supports an integrative view of the assessed changes.

4 RESULTS

A main emphasis of the study was set on the forest and its significance related to landscape changes. Generally, in Crans a steady and continuous increase in forested areas over more than 100 years could be observed whereas in Goms there was almost no change, in particular during the last 60 years (Tab. 1). The results of forested areas before 1933 (derived from Siegfried maps) and after 1941 (derived from aerial photographs) indicated this trend. A more quantitative comparison between the respective data sources (i.e. maps vs. remote sensing) was not possible since data availability required to set slightly different test areas.

The application of the official forest definition of the Valais (i.e. a minimum area of $800m^2$) on the forest classification results indicated that in Goms the portion of forest such as by definition slightly declined since 1941 although the overall forest area kept stable. This means that the amount of smaller forest patches and tree groups rised and forest became more fragmented. In Crans this trend was comparable but less significant.

Table 1: Total forest cover and forest cover considering only patches > 800m2 (official definition of forest) in percentage of total area

	Total forest cover (%)	Forest cover defined as $>800m^2$ (%)
Goms 1880	30.1	
Goms 1907	30.9	
Goms 1933	34.9	
Goms 1941	32.3	29.1
Goms 1994	32.2	27.8
Crans 1880	26.6	
Crans 1907	33.2	
Crans 1932	37.1	
Crans 1946	41.0	36.4
Crans 1998	44.5	39.1

In Crans topography has played an important role in the development of tourism infrastructure such that the area between 1400 and 1500 m.a.s.l. (plateau) has been affected most. For a closer insight forest cover changes were hence analysed in relation to elevation ranges. If then the number of buildings per time period and per elevation range is taken into comparison an interesting phenomenon is revealed: in the zone where contruction has been most effective (i.e. between 1400 and 1500 m.a.s.l.) a simultaneous small increase in forest can be found (Fig. 2).

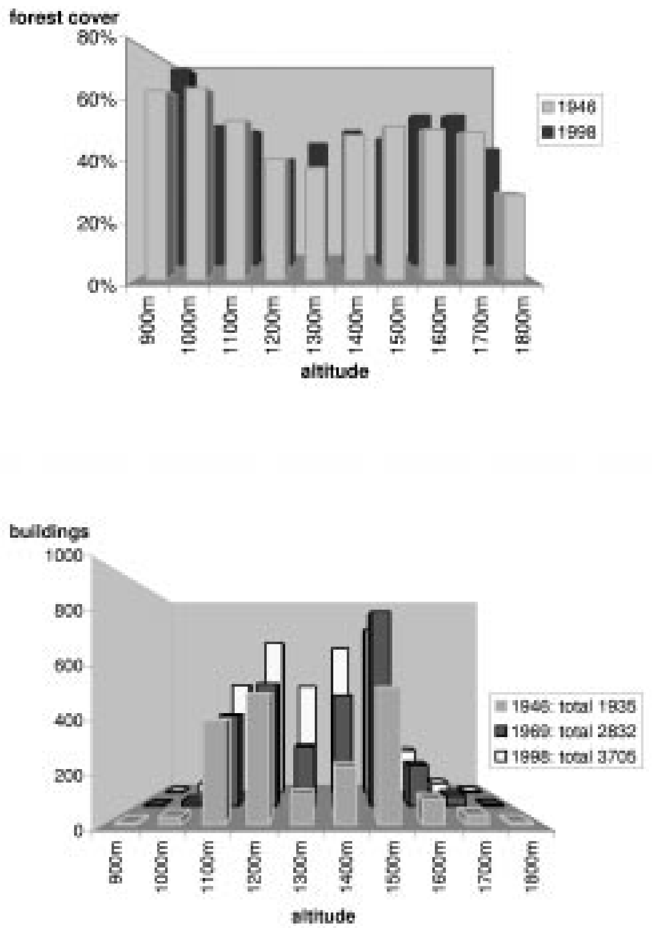

Figure 2. Crans: forest cover according to altitude in 1946 and 1998 (above) and number of buildings according to altitude in 1946, 1969 and 1998 (below).

Figures 3 and 4 visualize the strong construction activity in the elevation range between 1400 and 1500 m.a.s.l. in form of density maps of buildings. Two major trends were observed: first, the traditional villages on the lower range of the test region spread out from the core settlement zone. Second, the tourism station of Crans-Montana actually developed on terrain without any former traditional settlement and contrasts with the traditional villages by its extensive consumption of area (per building).

Table 2: Development of street length and number of buildings per hectare

	Total street length (km)	Buildings per hectare
Goms 1941	76.2	0.79
Goms 1967	76.0	0.97
Goms 1994	76.5	0.98
Crans 1946	159.6	0.93
Crans 1969	168.5	1.36
Crans 1998	156.8	1.78

The Goms region lacks any dramatic increase in construction of buildings. Before the Second World War the settlement area was nearly stable. In the last 60 years the rate of construction slightly accelerated but in principle the assumption of an untouched traditional valley was confirmed by these results.

In fact, the contrast from Goms to Crans can be exemplified particularly well by the measure 'number of buildings per area'. The very moderate growth in Goms in the last 60 years (even virtually no increase since 30 years) confronts the development in Crans where buildings almost doubled (Tab. 2). Evaluation of total street length points to a different context. In both test sites no major changes could be observed, a surprising fact at first sight but explainable in part by the applied classification where only one class was considered (including major streets to foot paths). In terms of topology of the street system, however, the results indicated that in Crans the tourism development caused a much denser system in some specific areas but as well the loss of a considerable number of minor roads in other (mainly agricultural) areas.

The comparison between the IRS-LISS forest classification (1997) and the one derived from aerial photographs (1998) deserves attention from a methodological point of view. As basically expected, the IRS classification gave a considerably lower number of overall forest cover (31% compared to 45% for the classification from aerial photographs). This was mainly due to scale differences (spatial resolutions of 23.5 m and 1 m, respectively) and since in Crans a high degree of smaller tree groups is found the coarser spatial resolution of IRS-LISS was not able to detect them. A full-processing classification could not yet applied on IKONOS data since preprocessing with respect to geometric rectification did not achieve the needed accuracy.

Figure 3. Crans: Forest cover and building density index in 1946.

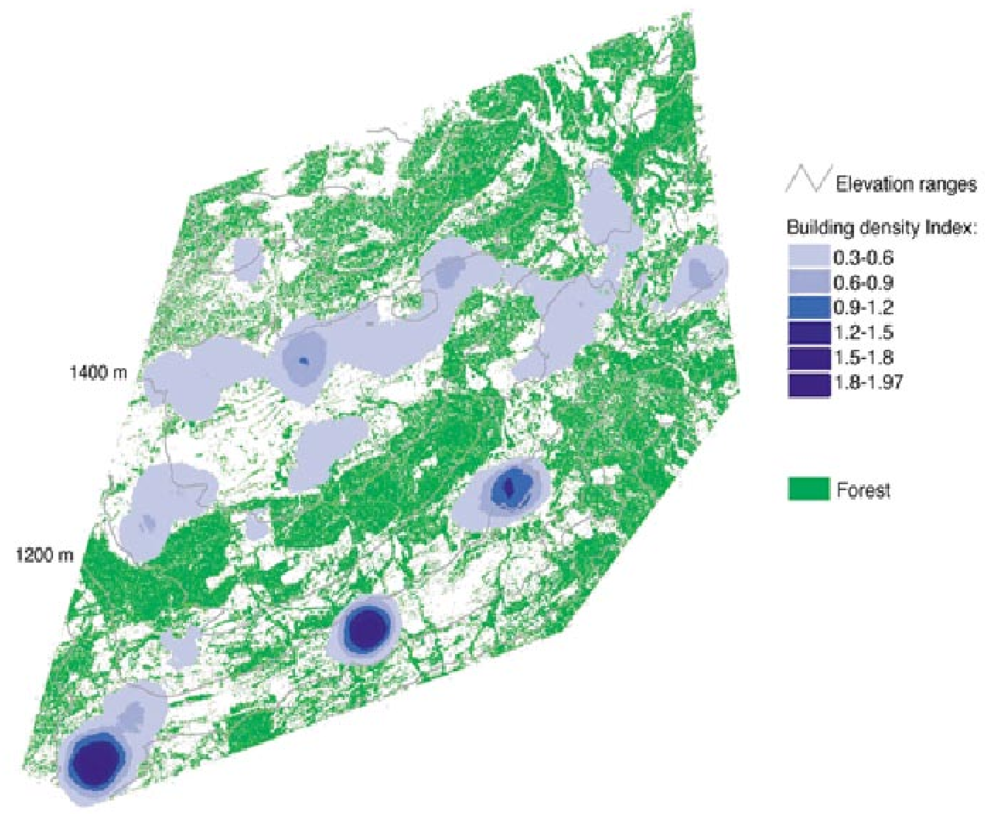

Figure 4. Crans: Forest cover and building density index in 1998.

5 DISCUSSION AND IMPLICATIONS FOR TOURISM PLANNING AND DECISION-MAKING

Since the implementation of the Forest Act in Switzerland at the end of the 19th century forest areas are growing for more than 100 years at moderate rates. This fact is quite well known to experts and confirmed by this study for the test regions. But what is far less known, especially to non-expert people involved in decision-making, is that despite massive tourism impact in certain alpine areas (such as Crans) forest cover has increased simultaneously.

Even so, more forest does not necessarily mean a higher ecological value or a more beautiful landscape. On the contrary, reforestation often comes along with a loss in ecologically valuable niches (Ewald 1978). A well-instructive example of landscape change in general and forest change in particular is shown in form of a time series of a selected area of Crans in 1946, 1969 and 1998 (Fig. 5). The forest in the upper part of the images has unsignificantly increased but its habit has been modified strongly by tourism-related infrastructure: cuttings for new roads and straightening of the forest edges, particularly relevant to ecology. Furthermore, forest has become denser. In the lower part of the images it is well distinguishable that forest or rather tree groups have evolved. The old, strongly fragmented agricultural field pattern (1946) has been gradually removed and later replaced by a golf course. The time series indeed visualizes the seeming paradox that massive construction can be accompanied by an increase in forest.

As far as the ecological value of the landscape is concerned it is concluded that ecologically valuable niches in Crans have declined during the development of tourism. ‘Fuzzy’ forest edges with transitional zones known for its high biodiversity (Dietschi 1992) have been straightened, single trees as well as shrubs and natural clearings have been removed to a great extent. Some decades ago, subsidies were actually granted by the Swiss Federal Government for cutting of single trees and shrubs in order to get a straight and well defined forest edge.

The degradation of agriculture in connection with tourism is as well represented by the case of Crans. Tourist industry has created new employments and in consequence land formerly used as pasture has got abandoned.

Coming back to the paradox at the heart of tourism development, i.e. the destruction of its own resources (in particular landscape), a crucial point for ongoing tourism development is how tourists percieve the changed landscape. According to Kaplan et al. (1989) complexity is generally a key index for landscape preference (mosaic of fields, closed forest

(a)

(b)

(c)

Figure 5. Crans: Time series of a part of Crans-Montana extracted from the orthorectified mosaic and showing the intense development between 1946 (a), 1969 (b) and 1998 (c).

and open woods). Landscape patterns such as diversity and interspersion seem to best express scenic beauty (Hunziker & Kienast 1999). Still, even for tourists, landscape perception is driven by more than one dimension, for instance tradition, nature conservation or emotion with the corresponding role of the landscape as cultural and natural heritage or as a recreation place (Hunziker 1995). The preservation of cultural and natural heritage is fulfilled to a much greater extent by Goms than by Crans as Figure 5 impressively demonstrated for Crans. The scenic beauty of the landscape is actually not the only factor in attracting tourists but more and more alpine locations with extensive wintersport facilities have become aware of the risk of destroying their landscape resources.

6 CONCLUSIONS

According to the results obtained in the selected alpine test sites intense tourism is a major force in modifying and forming the landscape. It has been clearly seen that in Crans, where tourism has developed at much higher rates than in Goms, the landscape has heavily changed. In Goms, on the other hand, the original situation from before the high period of tourism (i.e. around 1940) has been untouched to a higher degree, especially as far as settlements are concerned.

The assessment of long-term landscape changes such as carried out here requires the integration of data from various sources. In particular for the analysis of periods when satellite remote sensing data was not yet available voluminous preprocessing (mosaicking, radiometric corrections) has to be accepted.

In principle, the study demonstrates the advantage of high resolution remote sensing satellite data. Still, as seen here, multispectral sensors with spatial resolution in the range of 20 to 30 m (e.g. IRS-MS or Landsat-TM) hardly allow for the assessment of small changes which are often relevant in landscape evolution. Upcoming or recently launched sensors can close this gap as first tests with IKONOS data within CARTESIAN have shown.

ACKNOWLEDGEMENTS

This work has been carried out within the CARTESIAN project with financial support from the European Union (DGXII) and the Swiss Federal Office for Education and Science (BBW).

REFERENCES

Aerts, J., K. Seidel & H.-C. Bodmer 2000. CARTESIAN - Remote sensing based management information system for ski reource planning. *Proc. of the 20th EARSeL Symposium, Dresden* (to be published).

Afek, Y. & A. Brand 1998. Mosaicking of orthorectified aerial images. *Photogrammetric Engineering and remote sensing 64/2:* 115-125.

Conners, R.W. & C.A. Harlow 1980. A theoretical comparison of texture algorithms. *IEEE Transactions on Pattern Analysis and Machine Intelligence PAMI-2/3:* 204-222.

Dietschi, T. 1992. Der Waldrand als ökologische Ausgleichsfläche. *Schweizerische Zeitschrift fürs Forstwesen 143/7:* 542-547.

Ewald, K. 1978. Der Landschaftswandel. Zur Veränderung schweizerischer Kulturlandschaften im 20. Jahrhundert. Berichte Nr. 191, Birmensdorf.

Falencka-Jablonska, M., M. Kunz & A. Nienartowicz 2000. The application of aerial photographs for analysis of landscape diversity in Reserve Grzedy, Biebrza National Park, Poland. *Casanova, J.L. (Ed.), Proc. of the 19th EARSeL Symposium, Valladolid, Rotterdam: Balkema:* 67-73.

Hunter, C & H. Green 1995. *Tourism and the environment: a sustainable relationship?* London: Routledge.

Hunziker, M. 1992. Tourismusbedingte Landschaftsveraenderungen im Urteil der Touristen. *Geographica Helvetica 47/4:* 143-149.

Hunziker, M. 1995. The spontaneous reafforestation in abandoned agricultural lands: perception and aesthetic assessment by locals and tourists. *Landscape and Urban Planning 31:* 399-410.

Hunziker, M. &F. Kienast 1999. Potential impacts of changing agricultural activities on scenic beauty - a prototypical technique for automated rapid asessment. *Landscape Ecology 14:* 161-176.

Kaplan, R., S. Kaplan & T. Brown 1989. Environmental preference - a comparison of four domains of predictors. *Environmental behaviour 21:* 509-530.

Li, H.B. & J.F. Reynolds 1993. A new contagion index to quantify spatial patterns of landscapes. *Landscape Ecology 8:* 155-162.

McGarigal, K. & B.J. Mark 1994. FRAGSTATS - Spatial pattern analysis program for quantifying landscape structure. Oregon State University.

Qi, Y. & J.G. Wu 1996. Effects of changing spatial resolution on the results of landscape pattern analysisusing spatial auto correlation indices. *Landscape Ecology 11:* 39-49.

Turner, M.G. 1990. Landscape changes in nine rural counties in Georgia. *Photogrammetric engineering and remote sensing 56/3:* 379-386.

/home/seidel/BIWI_publ/EARSEL_huggel.frm