WHAT CONTRIBUTIONS CAN REMOTE SENSING MAKE TO HABITAT MONITORING OF THE E.U. HABITATS DIRECTIVE ARTICLE 11? - RESULTS OF RESEARCH IN BULGARIA, TURKEY AND ROMANIA

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ABSTRACT

The implementation of article 11 of the EU Habitats Directive (92/43/EWG) requires among others a long term monitoring of annex 1 habitats inside and outside Natura 2000 areas. Every 6 years the Member States have to present a national report including information about distribution, conservation status and trends (Article 17). An exhaustive biotope mapping provides a basis for these standards. Sometimes there are no suitable methods and data basis or the intensive mapping can not be achieved in a short or medium term. Two case studies in a high mountainous region (Central Balkan in Bulgaria) and a coastal region (Çukurova Delta in Turkey) set an example for the use of several remote sensing methods for habitat classification and evaluation. The research results will be transferred to the Romanian mountainous and coastal regions. Possibilities and limits of LANDSAT satellite data and aerial photographs will be presented. Therefore, conclusions of their applicability to meet the requirements of habitats and Natura 2000 areas are drawn.

Own researches show that air photographs are more suitable for habitat monitoring than satellite data. Also the quantitative assessment of habitats requires a relatively large scale for interpretations of at least 1:5000. Is the detection of habitat types impossible in spite of high resolution (e.g. alpine meadows), at least a searching area for potential annex 1 habitats can be localised. The habitat classification is for high mountainous regions more expensive than for plane coastal regions. The reasons are special geographical and climatic conditions. But for all that the exertion of remote sensing data is particularly suitable for areas that are difficult to access as well as wide areas with the occurrences of large area connected annex 1 habitats. The increasing impact because of land use to the Romanian mountainous and coastal regions requires an inexpensive, quick and area wide inventory and observation. In terms of quantitative monitoring an extensive control of preservation of Natura 2000 areas is required. By the use of a combined interpretation of satellite images and aerial photographs these make just a limited but important contribution to the evaluation of conservation status (qualitative monitoring). The large area surveillances of detecting impacts (e.g. deforestation, scrub encroachment, drainage, cultivation, damage) by remote sensing is there of particular importance.

REZUMAT: Ce contribuții aduce monitorizarea la distanță în cazul monitorizării habitatelor din articolul 11 al Directivei Habitate U.E.? - Rezultate ale cercetării în Bulgaria, Turcia şi România.

Implementarea articolului 11 a Directivei Habitate a UE (92/43/ EWG) necesită şi un monitoring pe termen lung a habitatelor anexei 1 în interiorul şi în exteriorul ariilor Natura 2000. La fiecare 6 ani Statele Membre trebuie să prezinte un raport incluzând informații referitoare la distribuție, starea conservării şi tedințe (Articolul 17). O cartare exhaustivă a biotopilor oferă baza pentru aceste standarde. Uneori nu există metode potrivite şi baze de date sau cartarea intensivă nu poate fi realizată în termen mediu sau scurt. Studii de caz în zone montane înalte (Balcanii Centrali în Bulgaria) şi o regiune de coastă - Delta Çukurova în Turcia) reprezintă exmple pentru utilizarea câtorva metode de urmărire la distanță pentru clasificarea şi evaluarea habitatelor. Rezultatele cercetării vor fi transferate în zone similare din România. Posibilitățile şi limitele datelor satelitului LANDSAT şi fotografiile aeriene vor fi prezentate. De aceea, sunt reliefate concluzii referitoare la aplicabilitatea acestora în condițiile habitatelor şi ariilor Natura 2000.

Cercetările noastre arată faptul că fotografiile aeriene sunt mult mai potrivite pentru monitorizarea habitatelor decât datele satelitare. De asemenea evaluarea cantitativă a habitatelor necesită o scară relativ largă pentru interpretări, de cel puțin 1:5000. Dacă detectarea tipurilor de habitate este imposibilă în pofida rezoluției înalte (ex. păşunile alpine), cel puțin o arie pentru habitate potențiale din anexa 1 pot fi localizate. Clasificarea habitatelor este mult mai scumpă pentru regiuni montane decât pentru regiuni de coastă. Motivele sunt reprezentate de condițiile geografice şi climatice speciale. Dar extragerea de date de la distanță în special pentru arii unde accesul este dificil sau necesită o analiză a unor spații întinse şi cu habitate din anexa 1, metoda este propice. Creşterea impactului datorat folosinței terenurilor în regiunile montane şi de coastă din România necesită o inventariere şi o observare rapidă, ieftină şi extinsă. În termeni de monitoring cantitativ este necesar un control extensiv a conservării ariilor Naura 2000. Utilizarea interpretării imaginilor satelitare şi a fotografiilor aeriene oferă o contribuție limitată dar importantă pentru evaluarea stării de conservare (monitoring calitativ). Supravegherea impactelor asupra unor arii extinse (ex. despăduriri, drenări, culturi agricole) prin monitorizare la distanță are o importanță particură.

ZUSSAMENFASSUNG: Welchen Beitrag leistet die Fernerkundung beim Monitoring der Habitate aus Artikel 11 der Habitatrichtlinie der EU? – Ergebnisse von Forschungsprojekten in Bulgarien, Türkei und Rumänien.

Die Umsetzung des Artikels 11 der EU-Habitatrichtlinie (92/43/EWG) erfordert auch ein Langzeitmonitoring der in Anhang I aufgelisteten Habitate innerhalb und außerhalb der Natura 2000 Gebiete. Alle sechs Jahre müssen die Mitgliedstaaten einen Bericht mit Informationen über Verteilung, Erhaltungszustand und Entwicklungstendenzen vorlegen (Artikel 17). Eine umfassende Kartierung der Biotope liefert die Grundlage für diese Standards. Manchmal gibt es jedoch keine entsprechenden Methoden und Datengrundlagen oder kann die Kartierung mittel- oder kurzfristig nicht durchgeführt werden. Fallstudien in hochmontanen Gebieten (Zentral-Balkan in Bulgarien) und in einem Küstengebiet (Çukurova Delta in der Türkei) liefern Beispiele für die Anwendung einiger Methoden von Fernerkundung für die Klassifizierung und Bewertung von Habitaten. Die Ergebnisse der Untersuchungen werden in ähnliche Gebiete Rumäniens übertragen. Die Möglichkeiten und Grenzen von LANDSAT Satellitendaten und Luftbildaufnahmen werden vorgestellt. Daher sind Schlussfolgerungen betreffend ihre

Anwendbarkeit unter den Bedingungen der Habitate und Natura 2000 Gebiete hervorgehoben.

Die vorliegenden Untersuchungen belegen, dass sich Luftbilder viel besser für das Monitoring von Habitaten eignen als Satellitendaten. Auch erfordert die quantitative und qualitative Evaluierung und Interpretation der Habitate einen relativ großen Maßstab, von mindestens 1:5000. Wenn die Herausarbeitung der Habitattypen trotz hoher Auflösung nicht möglich ist (z. B. bei den alpinen Weiden), kann zumindest ein Gebiet mit einem potentiellen Habitat der Anhangliste I geortet werden. Auch ist die Klassifizierung der Habitate viel teurer für montane Gebiete als für Küstenbereiche. Die Gründe dafür liegen in den geographischen und den besonderen klimatischen Gegebenheiten. Vor allem für Gebiete mit schwieriger Zugänglichkeit oder solche deren Analyse große Flächen erfordert und in denen Habitate der Anhangliste I vorkommen, ist die Methode der Datenerfassung durch Fernerkundung geeignet. Der wachsende, durch Landnutzung bedingte Einfluss in montanen und auch in Küstengebieten Rumäniens erfordert eine Erfassung sowie rasche, preisgünstige und großflächige Beobachtung, bzw. Überwachung der Flächen. Was das quantitative Monitoring betrifft, ist eine extensive Kontrolle des Erhaltungszustandes der Natura 2000 Gebiete erforderlich. Die Verwendung der Interpretation von Satellitenbildern und Luftbildern liefert einen begrenzten, aber wichtigen Beitrag für die Auswertung des Erhaltungszustandes (qualitatives Monitoring). Die Überwachung von Eingriffen in ausgedehnten Gebieten (z. B. Waldrodungen, Entwässerungen, Ackerflächen) mittels Flächenmonitoring durch Fernerkundung hat eine besondere Bedeutung.

INTRODUCTION

The European Union is seeking to ensure biodiversity by conserving natural habitats and wild fauna and flora in Member States. Therefore, the Habitats Directive 92/43/EEC is one of the most important instruments of nature conservation at European level. The Directive establishes an European ecological network known as "Natura 2000". The network comprises "special areas of conservation" designated by Member States in accordance with the provisions of the Directive. Article 6 of the Habitats Directive obligates Member States to preserve and establish the favourable conservation status of species and habitats (Management). General surveillance of species and habitats of Community interest is covered by Article 11 (Monitoring). These must be observed inside and outside Natura 2000 areas. Every six years, Member States must report on the measures they have taken pursuant to the Directive (Article 17, Reporting).

The Habitats Directive implementation often poses difficulties for the Member States. The preliminary work necessary is time-consuming. Comprehensive scientific data of species and habitats distribution have to be recorded according to the Habitats Directive outlined requirements (Homeyer and Klaphake, 2001). The development of management concepts and monitoring schemes requires a rough but comprehensive inventory of potential conservation objects. The habitat mapping and evaluation method to be used is therefore of great importance. The Central European standards in place can not be simply adopted; they must be adapted and further developed in a methodical way and adjusted to the specific situations in the new and future Member States. The development and application of efficient data acquisition methods is required because of the large areas to be covered, insufficient records and limited financial resources. The necessary inventory, particularly for the Carpathians and the large coastal ecosystems of the Black Sea, cannot be made through terrestrial mapping only. As for the monitoring of habitats of Community interest in Romania, cheap remote sensing methods are highly relevant. The large area of the Romanian Carpathians and the Romanian Black Sea Coast along 245 km, are rich in habitats of Community interest and include a huge number of Natura 2000 areas. Romania possesses 91 of 218 habitat types of Community interest. 48 thereof are located in the alpine zone (Carpathians) and 29 in the pontic zone (Black Sea Coast) (Ordinance 52/2003).

In this article we present two research projects using remote sensing data (LANDSAT satellite photos, aerial photographs) to classify and evaluate habitat types. One case study is located in a mountainous region (Central Balkan, Bulgaria) and one in a coastal region (Çukurova Delta, Turkey). In this article, the opportunities and limitations of LANDSAT satellite data and aerial photographs will be presented and conclusions will be presented concerning their relevance in meeting the monitoring requirements of natural habitats and Natura 2000 areas. The results will then be applied to the Romanian mountainous and coastal regions. Furthermore, we will illustrate some results of a current research project in the Southern Carpathians and argue for the necessity of integration field-based methods using beech forests as an example.

Research in Bulgaria and Turkey

The research projects in the Central Balkan region in Bulgaria (Tischew et al., 2005) and in the Çukurova Delta coastal region in Turkey (Tischew et al., 2004) deal with the goal of applying remote sensing data to yield cost-efficient processing of large areas which have been little-researched for nature conservation and landscape planning purposes. The central issues of the studies are the classification, survey and evaluation of habitats. Before analysing the remote sensing data of both research projects a habitat type classification scheme was developed. This was based on a survey of the literature available and field-based vegetation data sampling.

In order to pursue our research goals, we analysed satellite image data of the Çukurova Delta. Objects and details down to a scale of 1:50,000 could be detected. In the Central Balkan project we analysed satellite images as well as our own aerial photographs. These aerial photographs were used to develop a low-cost remote sensing system. Objects and details down to a scale of 1:5,000 could be detected here. For the data analyses, we used the free software GRASS GIS, which would cut costs in offices and institutions as well as NGOs.

Both projects were carried out by Anhalt University of Applied Sciences (Germany) in cooperation with Çukurova University and the administration of the Biosphere Reserve Çukurova Delta and National Park Central Balkan.

Mountainous ecosystem: Central Balkan (Bulgaria)

Pilot area, goals and methods

The goal of the project was to draft and test a procedure for mapping, classification and evaluation of potential Natura 2000 habitats in large areas and areas that are difficult to access. We combined traditional field methods of vegetation mapping and remote sensing methods using satellite data and airplane-mounted digital camera data (Tab. 1). The aerial surveys we did took place in the Tsarichina reserve. The area studied is 34 km^2 and has an altitude of 700 m - 2198 m above sea level. Its terrain ranges from mountainous to alpine.

Table 1: Remote sensing data.

<table>
<tr><td colspan="3">Project Central Balkan, Bulgaria</td></tr>
<tr><td>Satellite photos</td><td colspan="2">Sensor: LANDSAT 7 ETM+
Recording date: 21.06.2000, WRS path: 183, WRS pow: 30
Digital aerial photographs
TetraCam (RGB + NIR)
Recording date: spring and late summer 2004, summer 2005
Resolution: 1000 m; flight strip width = 1.70 m
Picture size: 1000 m; above ground = 800 m x 600 m
Flight route and technical date of the flight
areal cover: min. 600 m x 500 m; coverage of one flight strip (7 aerial photographs): 3500 m x 600 m; time per flight strip: aprox. 5 min
Topographic map: 1987; 1:50,000</td></tr>
<tr><td colspan="3">Project Çukurova Delta, Turkey</td></tr>
<tr><td>Satellite photos</td><td>Sensor: LANDSAT 5 TM
Recording date: 25.04.1985
WRS path: 175
WRS row: 35</td><td>Sensor: LANDSAT 7 ETM+
Recording date: 05.05.2003
WRS path: 175
WRS row: 35</td></tr>
<tr><td colspan="3">Used in both projects:
Digital elevation model: SRTM3
Sensor: Shuttle Imaging Radar C (SIR-C); Recording date: 11.02. - 22.02.2000;
Spatial ground resolution: 90 m; Spatial height resolution: 10 m</td></tr>
</table>

Because the new Member States of the EU only have limited financial resources for environmental protection, we aimed at developing and testing a low-cost remote sensing system. Low-cost remote sensing means aerial recording techniques with inexpensive recording devices such as medium format and 35 mm cameras (Frazier et al., 1994), digital cameras (King, 1994) and video cameras (Redd et al., 1994; Nowling and Tueller, 1994). The uses of low-cost systems are similar to those of conventional aerial photography. However, they have been seldom employed (Traxler, 1997).

After drafting a classification scheme of habitats and vegetation structures, we then detected habitat types via satellite data and digital aerial photographs made from our own aerial survey. We checked what level of classification was feasible. This depended on to what extent different habitat types, which were spectrally difficult to distinguish, had to be combined in order to enable their detection using remote sensing data. We also checked whether the system was suitable for monitoring the conservation status. Special structural parameters important to habitat management were taken into account (e.g. scrub encroachment of sub-alpine grasslands and heaths, detection of current or former clear-cutting areas or illegal felling).

The remote sensing data used included satellite photos of LANDSAT 7 ETM+ as well as aerial photographs from our own aerial survey. We made three surveys in 2004 and 2005 in two areas of the reserve. A TetraCam MCA was used. At the same time with the aerial surveys, we also conducted fieldwork. This included recording ground control points and training areas, mapping wooded areas and revising and developing the habitat type classification scheme. All dominant and representative plant species which roughly enable vegetation mapping (association level at the most) in a total of 60 training areas were included. An analysis phase preceded each round of field study. This included georeferencing and visually classifying the aerial photographs as well as evaluating vegetation mapping of the training areas. Finally, we classified the entire area under investigation (using semi-automatic means) and in the third field study, evaluated it by random sample.

RESULTS

Using satellite photos, we were able to classify the following habitat complexes: deciduous forests [beech (fir) forests], evergreen forests [Norway spruce forests (pine forests)], heaths (grassland heaths, tall herb grounds, different phases of scrub encroachment), and grass grounds (sub-alpine - mountain) and areas which are almost devoid of vegetation as well as vegetation-free areas like crags, screed or gravel. There were difficulties in classifying mixed forests, e.g. beech-fir forests, which were mostly classified as being deciduous forests because they were spectrally dominant at those sites. Also, there is a fine line between sub-alpine heaths and sub-alpine grasslands. This manifested itself in mixed pixel images which were difficult to differentiate. An invasion by grasses in several heaths in the area investigated also magnified this effect.

In the figure 1, it can be seen that the classification of aerial photographs is much more detailed and on a much smaller scale. On the photos, the rough zoning is accurate, but smaller areas are lost, blending in with the larger, differently classified surrounding areas. The higher spatial resolution of the aerial photographs helped in recording heath habitats, for example, since different vegetation classes could be determined more easily than on the satellite photos. Juniper heaths can be clearly distinguished from the more species-diverse vaccinion/bruckentahalion heaths. Further differentiation of the sub-alpine grass grounds was not possible even using the data from the aerial surveys. Table 2 also shows a comparative overview of the detectability of habitat types using the data from the satellite photos, the aerial photographs and from our habitat type classification scheme.

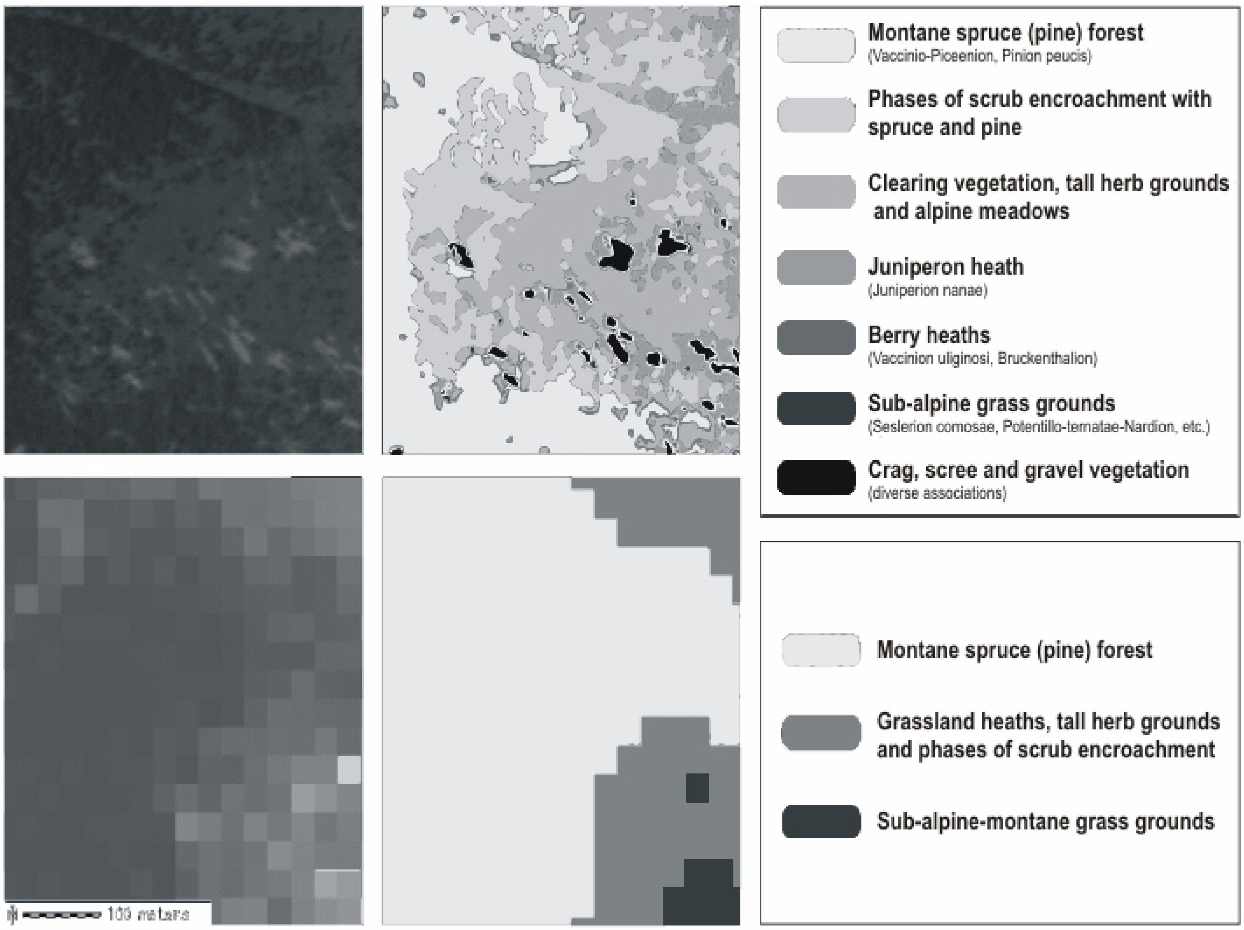

Figure 1: Aerial survey area 1, above: area detail of aerial photo from the TetraCam (left: original aerial photo, right: classified area detail), below: image of the same area using a LANDSAT satellite photo (left: unclassified photo, right: classified photo).

Table 2: Determination of habitat types at different survey levels in the Central Balkan (In parantheses: Natura 2000 code).

<table>
<tr><th>Satellite image</th><th>Aerial photographs</th><th>Terrestrial classification</th></tr>
<tr><td rowspan="2">Coniferous forest</td><td rowspan="2">Coniferous forest</td><td>Vaccinio-Junipero-Piceetum subalpinum (9410)</td></tr>
<tr><td>Pinetum peucis typicum</td></tr>
<tr><td rowspan="5">Mixed deciduous forest</td><td>Beech-fir-forest</td><td>Abieti-Fagetum moesiacum</td></tr>
<tr><td rowspan="4">Beech forest</td><td>Luzulo-Fagetum (9110)</td></tr>
<tr><td>Galio-Fagetum</td></tr>
<tr><td>Asperulo-Fagetum (9130)</td></tr>
<tr><td>etc.</td></tr>
<tr><td rowspan="6">Grassland heaths, tall herb grounds and phases of scrub encroachment</td><td>Different phases of scrub encroachment with spruce and pine</td><td>Different phases of scrub encroachment with spruce and pine</td></tr>
<tr><td>Clearing vegetation, tall herb grounds, alpine meadows (over-manured)</td><td>Diverse associations and communities (e.g. Cirsion appendiculati, Rubetum idaei)</td></tr>
<tr><td>Juniper heaths (4060)</td><td>Juniperion nanae</td></tr>
<tr><td rowspan="3">Berry heaths (4060)</td><td>Bruckenthalion</td></tr>
<tr><td>Vaccinion uliginosi</td></tr>
<tr><td>etc.</td></tr>
<tr><td rowspan="3">Montane - sub-alpine grass grounds</td><td rowspan="3">Montane - sub-alpine grass grounds</td><td>Nardion (6230*)</td></tr>
<tr><td>Seslerion</td></tr>
<tr><td>etc.</td></tr>
<tr><td>Crag, scree and gravel vegetation</td><td>Crag, scree and gravel vegetation</td><td>Diverse associations and communities</td></tr>
</table>

DISCUSSION

Problems with the aerial surveys and data

Because of highly variable weather conditions in Central Balkan National Park, there were problems in completing the aerial surveys. Because of the unpredictable weather conditions in the mountains and sudden fluctuations in weather patterns, aerial surveys under optimal conditions were very difficult to plan. Because of this, less-than-optimal aerial surveys and the data resulting from them could not be ruled out. During the aerial survey conducted in the spring, low-lying clouds forced the airplane to fly at a lower altitude, so complete coverage of the area was not possible using the TetraCam. The aerial survey in the summer could not be conducted midday, which caused longer and harder shadows.

In summer, the mostly heavy cloud formations over the Balkan Mountains are also seen on the LANDSAT satellite photos. Because of this, we had to resort to satellite pictures from 2000, since all later images were unusable due to overcast skies.

The TetraCam used was only suitable to a limited extent. This was due to the fact that the individual objectives were extremely sensitive to changes in light conditions, which greatly affects picture results in high mountain regions (frequent alternation of lighted areas and shaded areas). Because of this sensitivity, the brightness fluctuates greatly on several of the aerial photographs. This made (semi-) automatic classification more difficult and increased the amount of corrections which had to be made after the fact. There was also a problem with the (semi-)automatic classification of the aerial photo mosaic because of these differences in brightness (Hörsch, 2001).

Also, the camera was prone to malfunction during the summer aerial survey, since the NIR function sometimes did not work. The georeferencing of the aerial photographs proved to be very difficult and time intensive due to image distortions caused by the constantly changing relief.

Opportunities, limits and suitability of the method

Our project in Central Balkan National Park shows that a blanket inventory of habitats of Community interest and their exact determination and designation could not be produced with the techniques used in the project. For an exact designation of habitat types of Community interest, a differentiation of the vegetation is necessary at least on the association level and in some cases on the plant community level. Habitat types of Community interest could only be detected on the class level (association level at the most) using the satellite data and the aerial photo data. The method is suitable for forest habitat types, which are often present in mountainous regions, if the composite of tree species is clearly demarcated (e.g. beech-fir forests and beech forests). The different forest types (beech, beech-fir and spruce forests) could be distinguished very well via aerial photo classification in spite of the different valley exposures caused by large differences in brightness. Forest habitat types, which only differ from each other because of the species composite of the herb layer (e.g. beech forests), were more problematic. These can only be described as a unit. Using aerial photographs, heaths could be classified very well. There were problems differentiating sub-alpine grass grounds. Ecotone and border areas, such as chamaephytes on the edge of woodlands or the invasion by grasses of chamaephyte heaths changing over to sub-alpine short grass communities, were very difficult to differentiate because of extreme mixed pixel effects. It was especially difficult to suitably differentiate the classes of the complex patterns of the smallest habitat areas of different vegetation types above the timber line. Because of this, this method is not yet suited to distinguish fine vegetation structures, like for example differentiating vegetation types from alpine grasslands or sub-alpine heaths, which differ from each other very little spectrally.

In order for the methods used in the project to be suited for practical use, the technology used needs to be optimised. In the high mountains, a camera not as prone to be disturbed by differences in brightness needs to be used. Moreover, ways need to be found to reduce the current amount of work involved in georeferencing the aerial photographs and in visual classification using (semi-)automatic classification methods. Though the continual development and improvement of technology, these problems will probably be overcome in the medium-term.

Coastal ecosystem: Çucurova Delta (Turkey)

Pilot area, project goals and methods

The coastal ecosystem Çukurova Delta is located on the south-eastern Turkish Mediterranean coast. The Çukurova is a typical delta basin and one of the largest river drainage basins flowing into the Mediterranean Sea. In spite of extensive and dramatic man-made alterations, it is one of the most important Mediterranean wetlands and continuous coastal ecosystems on the Turkish Mediterranean coast. The area is characterised by high ecological diversity rich in fauna, flora (Altan and Yucel, 1987). With a 110 km long coast, Çukurova Delta encompasses an area of about 5000 km² (Kuleli, 2005).

The project goal was to develop an operations manual for the classification of habitats, land coverage and land use by using inexpensive and practicable LANDSAT data (Tab. 3). In combination with GRASS GIS software, we intended to research the opportunities and limits of this low-cost method. At 80 training sites we recorded vegetation, land use intensity, degradation and other relevant abiotic parameters.