

Adequate Decentral Management for Environmental Monitoring of Very Large Areas

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Abstract

A project of technical cooperation between Argentina and Germany investigates the severe desertification process in Patagonia. In order to establish a both effective and economical monitoring procedure, data processing is concentrated in five different places, based on LANDSAT imagery and GIS techniques. To cover the large area of approx. 800 000 sqkm completely, four transects from the ANDES to the Atlantic had been defined and checked in detail with interpolation using NOAA imagery.

Zusammenfassung

Ein Projekt der technischen Zusammenarbeit zwischen Argentinien und Deutschland untersucht den starken Desertifikationsprozeß in Patagonien. Um ein zugleich effektives und wirtschaftliches Verfahren durchzuführen, wird die Datenverarbeitung auf 5 verschiedene Stellen verteilt, wobei LANDSAT-Bilder und GIS-Techniken angewandt werden. Vollständig erfaßt werden die ca. 800 000 qkm durch Interpolation mit NOAA-Bildern zwischen 4 Transsekten von den Anden zum Atlantik, für welche Detailinformationen vorliegen.

1 Desertification - a World-Wide Problem

„Desertification“ means the degradation of environment in terms of transformation from vegetation-covered soil to conditions which are hostile to men and inadequate for agriculture or animal production. Society is growing aware of that problem since it occurs in many regions of the earth and often manifests in spectacular disasters which claimed thousands of lives like in the Sahel or in Somalia.

Desertification being a fundamental problem for mankind, the UN organized a conference in Nairobi (UNCOD 1977) which was the starting point for many national and international activities in that field.

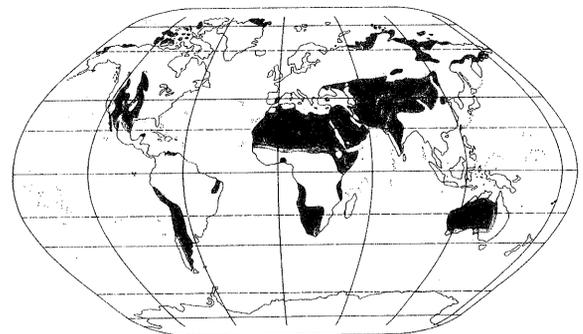


Fig. 1 Desertification on Earth

Black: High risk

Grey: Lower risk

Sources: UNCOD 1977 and MENSCHING 1990

Fig. 1 gives an overview of the vast extent of desertification. This must be seen on the background of growing population rates and the many efforts to expand food production. The components „population“ and „food production“ are at present one of the major social and technical challenges - and will probably continue to be so.

Desertification occurs due to many different reasons (see MENSCHING, 1990 for an excellent systematization), depending both on human and natural factors. The phenomenon may even start when only one of these two factors is present. However, in most cases it is the combination of both that results in the process called „land degradation“. Remote Sensing techniques represent a very effective means for monitoring large areas. Consequently, it is a basic tool for a binational project on desertification control in Argentina/Patagonia.

2 Natural and Social Conditions in Patagonia

Patagonia lies in the southern part of South America between 36° and 55° latitude south, approx. The area is divided by the Andean Range into a western and an eastern part which belong to Chile and Argentina, respectively. Only the eastern side is affected by desertification, i. e. the Argentine Provinces Neuquén, Rio Negro, Chubut and Santa Cruz. They cover an area of about 800 000 sqkm which is equivalent to the surface of Germany plus Poland plus Czechoslovakia.

Extent and quality of the desertification process has been largely studied and analyzed by different official Institutions and governmental agencies but this information is scattered and not readily available.

The official statistics give 70 % desertification for Argentina as a whole including Patagonia. This means that in principle all Provinces are affected. One may get an idea of its political impact taking into account that agriculture and livestock were the base for the nation's economic and social balance.

There are multiple reasons for desertification in Patagonia. They are the result of natural conditions and human activities. Conditions for agriculture activities including animal production have never been favourable due to topography and the prevailing climate which do not offer suitable alternatives for investment. The „environmental balance“ is very sensitive to minor changes of the parameters.

From these parameters we have selected two in order to show how the degradation process works:

a) As a natural factor we take the precipitation rate. It is evident that the Andean Range acts as a barrier: rainfall values drastically go down from 2 000 mm to 200 mm from west to east. The most striking factor is that this gradient occurs within a distance of only 100 km or even less. As a consequence, only a very small strip at the Andes receives sufficient rainfall. „Sufficient“ means a rate in the order of 500 to 1 000 mm, depending on latitude, topography and soil type.

The Andes are the dominating feature governing the natural conditions in Patagonia; even temperatures do not only follow a north-south gradient, but a strong east-west gradient as well. Compared to the northern hemisphere, the mean annual temperature of 10° C at 42° C latitude (corresponding to Roma, 15° C) is extremely low.

b) As to land use, sheep farming is the most important factor. Sheep are almost exclusively reared for wool production. In the period from 1888 to 1908 the animal population grew from 290 000 to 4.3 million, reaching 12 million in 1983. This resulted in heavy overgrazing which is one of the most significant factors for desertification caused by anthropogeneous activities in this very sensitive environment.

Since rainfall and other natural processes may not easily be influenced by man, desertification control should start with those factors dominated by him like sheep farming, for example. However, one has to take into account social and political constraints which actually turn out to be stronger than all arguments forwarded by science.

3 Environmental Monitoring Using GIS-Technology

Monitoring the environment will provide details about the interaction of the various parameters involved in the desertification process. The analysis finally will lead to a quantitative model, which may be applied to an area where the necessary data are available. This will result in information about the status of the environment, which should be one of the basic elements to decide about feasible control measures.

The process is depicted in the diagram of Fig. 2.

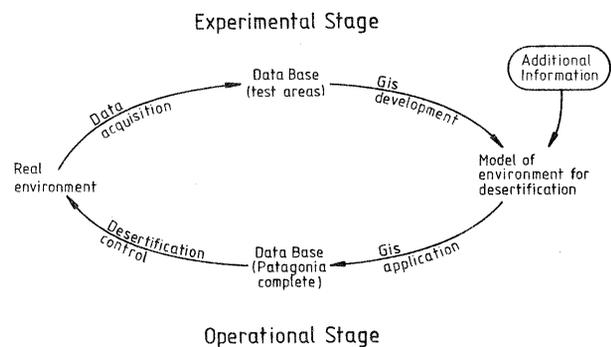


Fig. 2 Scheme for Environmental Monitoring Using GIS Technology

In a first step, a „Model“ must be set up taking into account the most significant parameters involved. This model should be drawn from the real environment, or, more specifically, from data acquired, for example, by Remote Sensing Techniques or in some other way.

The most important step is the development of a GIS. It consists of a model of the environment for desertification analysis. This essential task may only be accomplished by interdisciplinary work, by the joint effort of ecology, soil science, biology, sociology, hydrology and data processing experts. The establishment of a GIS requires data from well-known test areas used like „training fields“ as for multispectral classification.

The GIS will be the basis for providing the following features:

1. Type and degree of desertification
2. Endangered areas, probability of desertification

According to Fig. 2, the GIS will have to be applied to the data base for the whole Patagonian territory. Thus we proceed from the „experimental stage“ to the „operational stage“. During the initial phase, activities concentrate on data acquisition, first in test areas, then for the whole area under consideration. Establishing the desertification model and processing the complete data base gives a level of information which allows to draw conclusions about activities in the real environment.

Knowing the extent of desertified and endangered areas, finally provides the necessary detailed information to formulate appropriate desertification control measures.

4 International Cooperation: Project „Desertification Control in Patagonia“

Under the name of „Desertification Control in Patagonia“ (Lucha contra la desertificación en la Patagonia), a Project of Technical Cooperation between Argentina and Germany was defined in 1987. The official support was given by the respective Ministries whereas the realization was trusted to INTA (Instituto Nacional de Tecnología Agropecuaria) and GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit). Since the operation was to be carried out in Patagonia, the headquarters were installed with the regional INTA-group in San Carlos de Bariloche (Province of Rio Negro). Head of the German Counterparts is Dr. J. Goergen.

The project started in 1990 will run for at least 4 years. The regional INTA group provides an excellent base of knowledge and data for desertification research. On the other hand, data acquisition by Remote Sensing as well as GIS technology is introduced by the German counterparts. Because of the large range of necessary activities, experts from different fields are contracted when required. Technical backstopping is provided by the IPF (Institut für Photogrammetrie und Fernerkundung, University of Karlsruhe).

The final goal of the Project means „control“, i. e. improvement of the present situation. Consequently, High-tech features like Remote Sensing and GIS technology must be regarded as efficient tools - no more but no less.

5 Technical Procedure for Data Acquisition

The initial stage of the Project is characteristic for difficulties which are common to many environmental

problems, particularly in remote areas. Among these the lack of updated topographic base maps is typical.

Though there fortunately exist in Patagonia topographic maps in Gauss-Krüger-coordinates, which provide the geodetic reference, their content and status do not allow any environmental monitoring. Nevertheless we should point out that those topographic maps contain height information which is important for most environmental projects. The map scale for Patagonia is not consistent: it varies from 1:100 000 to 1:250 000. However every area is covered by a map, no matter in what scale. INTA and other agencies have already done a lot in land degradation surveys, soil and vegetation mapping, etc.

But some areas are only sporadically well covered, like Maquinchao (see paragraph 6). A homogeneous, complete, informative data base is only provided by satellite imagery. Airborne photography does not seem to be an adequate tool for environmental monitoring of Patagonia as a whole: the area involved is too large; the spectral resolution is poor, even for colour IR-imagery; and finally, data processing should be performed in the digital domain, because of the necessary analysis by GIS.

800 000 sqkm represent a „very large area“ when monitoring land degradation even for satellite imagery. Therefore a hierarchical system has been established:

Patagonia (the whole region) - NOAA data
4 Transects - LANDSAT MSS
Representative areas - LANDSAT TM,
Special imagery and field check.

The satellite imagery used does not require further comments (BÄHR, 1991). A novelty lies in the procedure for mapping the area by the hierarchical approach. Transects (Fig. 3) carefully defined by Geo-ecological experts cross areas where specific information has already been mapped.

Each transect is covered by 3 to 5 LANDSAT scenes. While Patagonia as a whole would require approx. 50 scenes, only 15 are needed for these transects. Coupled with the available ground data, detailed analysis will reveal the desertification processes taking into account the specific types of phenomena involved which vary considerably from one transect to the other.

Beside the transects, it is necessary to go into further detail - since even the individual plant serves as an indicator for desertification! Consequently field check and large-scale mapping is also required. This is done in „representative areas“ of particular interest (e. g. Maquinchao - see paragraph 6). Here all useful data are compiled by means of field work or Remote Sensing Techniques. On the other hand, the capability

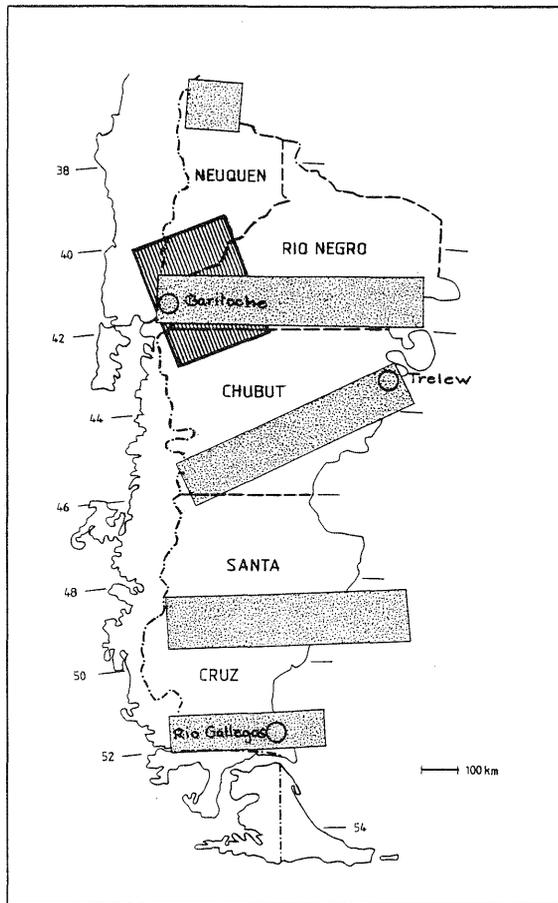


Fig. 3 Localization of Transects and Data Processing Units

of the latest sensors (like ERS-1, for instance) may be checked in these areas.

The final system for data acquisition in the transects is displayed in Fig. 4.

There exist 4 marked data lines:

1. Interpretation of LANDSAT-MSS imagery
2. Digital multispectral classification
3. Geocoding
4. Digitizing of line maps

All four data streams flow finally into data bases (GIS archives) after geocoding them to a common system.

A prerequisite for effective and correct interpretation or classification is ecological knowledge of the ecosystem of the area. The respective information is drawn on maps (topographic work sheets - 1:250 000), plotted on the base of digitized topographic maps.

The gaps between transects are filled by interpolation. Here NOAA data are applied (see paragraph 6).

Beside the transect approach coupled with interpretation of NOAA imagery, another arrangement will increase the efficiency of data processing in the large area: the decentralized distribution of data processing laboratories. This has been arranged due to the conviction that:

1. Regional groups should perform the data processing since they have a deeper knowledge of the local desertification indicators
2. Summing up the potential capacity of a number of separate units will be more efficient than burdening the central unit with the whole work
3. A central laboratory is more exposed to possible disasters than the separate ones together
4. The learning effect is higher in smaller individual units as more operators are involved for the whole project. Exchange of experience stimulates people.

In fact, 3 data processing laboratories have been installed in Patagonia, as shown in Fig. 3. All of them are with the local representation of INTA.

In Bariloche, two units are available; outside Patagonia there exist two more, one at the University of Buenos Aires/IFEVA (Prof. Soriano), another in Mendoza with IADIZA. The basic hardware configuration, nearly identical for all laboratories, is shown in Fig. 5.

The PC-controlled system does not include a precision recorder for image output but only an ink jet plotter for quick look.

Software in ERDAS, as raster processing seems to be more adequate than vector processing. This is because the structure of ecological data corresponds better to pixels than to lines since limits are never „exact“ like for instance in cadaster. Moreover, many of the basic data - like satellite imagery - are in raster format. Nevertheless, the many different data involved require a vector system, too (ARC/INFO). It is mainly welcome for digitizing conventional line maps, but also for registering non-spatial data. The final ultimate data base („archives“ in Fig. 4) is in raster format after vector-raster transformation of the ARC/INFO controlled digitized line maps.

6 Preliminary Results

Operational work is performed in Argentina, principally at the INTA stations for the particular transects. These activities are accompanied by special research at the University of Karlsruhe.

An important question refers to the role of NOAA data. High temporal resolution is a positive factor, whereas the geometrical resolution of less than 1 km represents a limiting factor. Nevertheless, NOAA data may be used for

Interpolation between the transects
Detecting seasonal changes in Patagonia as a whole

As a first step, a poster in 1:1.5 million was produced in order to give a general overview of Patagonia. The result shows obvious regional differences especially the degradation effect starting from the Andes eastbound and the basaltic central meseta, starting from 40 S southbound.

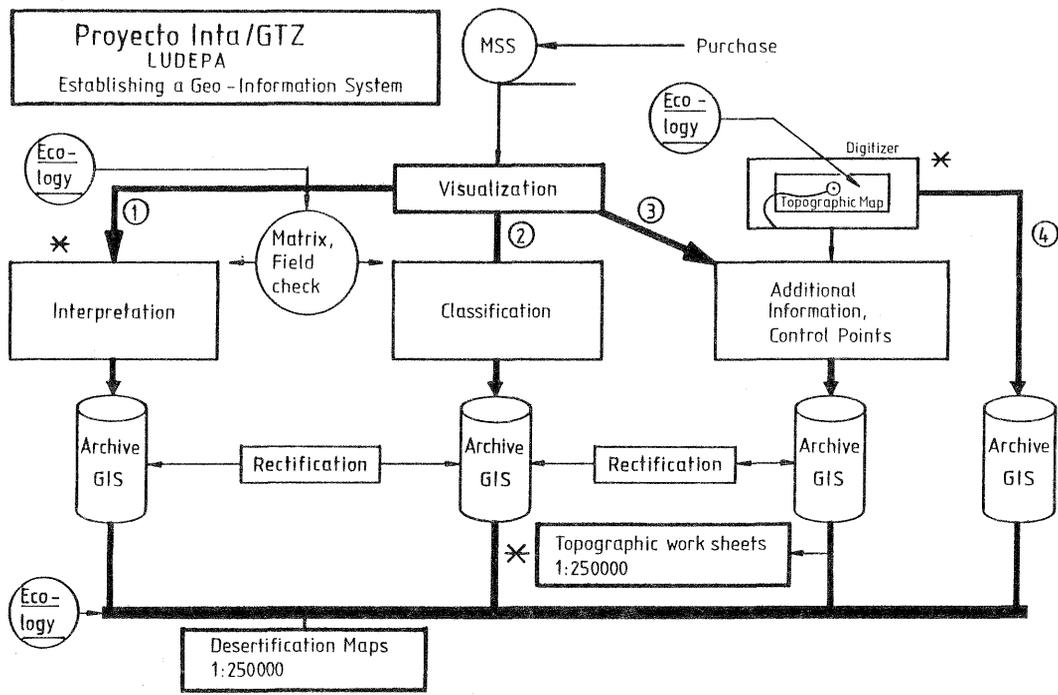


Fig. 4 Data Acquisition in Transects for a GIS Data Base „Desertification Control in Patagonia“

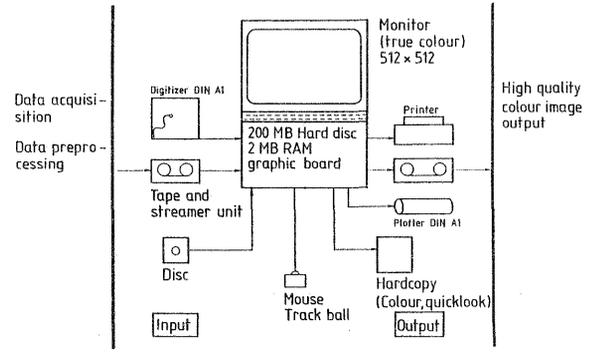


Fig. 5 Hardware configuration for a Data Processing Unit

The issue of seasonal changes, taking into account precipitation etc. has not yet been considered, but interpolation seems to be possible.

The quality of LANDSAT MSS data for detecting desertification processes was checked in a test area („Jacobacci-Maquinchao“) where good ground truth is available. The area, between 41°00' and 41°25' S and 68° 20' and 70° 20' W , had been mapped for a FAO/INTA project, applying conventional interpretation of airborne imagery 1:40 000 and field work. The results have been carefully documented in the literature (see SPECK et al., 1982), which served as a reference.

A physiographic map from SPECK was digitized and laid over the respective LANDSAT MSS scene (Fig. 6). The result shows clearly that nearly all physiographic features which had been defined in the 1:40 000 black and white aerial photography are

detectable in the LANDSAT MSS imagery. Moreover, some areas are even represented in more detail than by the map, like the eolic pattern around the basin of the lake. Of course, only colour may give the full, correct information.

For the 29 different physiographic classes defined in SPECK et al. (1982) and delineated in Fig. 6, some examples are given, corresponding to the numbers 1 to 5 in Fig. 6:

1. Permanent lake in old lake basin, large saline tongue originated by eolic (wind) deposition
Ancient parallel shorelines with saline areas at the lower zones
2. Main channel with seasonal flow, covered by moderately dense vegetation
3. High undissected basaltic plateau with steep scarpments
4. Low undissected basaltic plateau, some bush vegetation
5. High basaltic plateau with many small shallow saline depressions

All classes, except (2), show severe desertification. Geometric precision of the class boundaries is somewhat problematic and can not be treated analytically, as there exist a strong correlation between the „linguistic precision of class definition“ and the boundaries. Due to many reasons, we detect obvious differences between SPECK's vector map and LANDSAT MSS, particularly for the channels covered by vegetation (class 2).

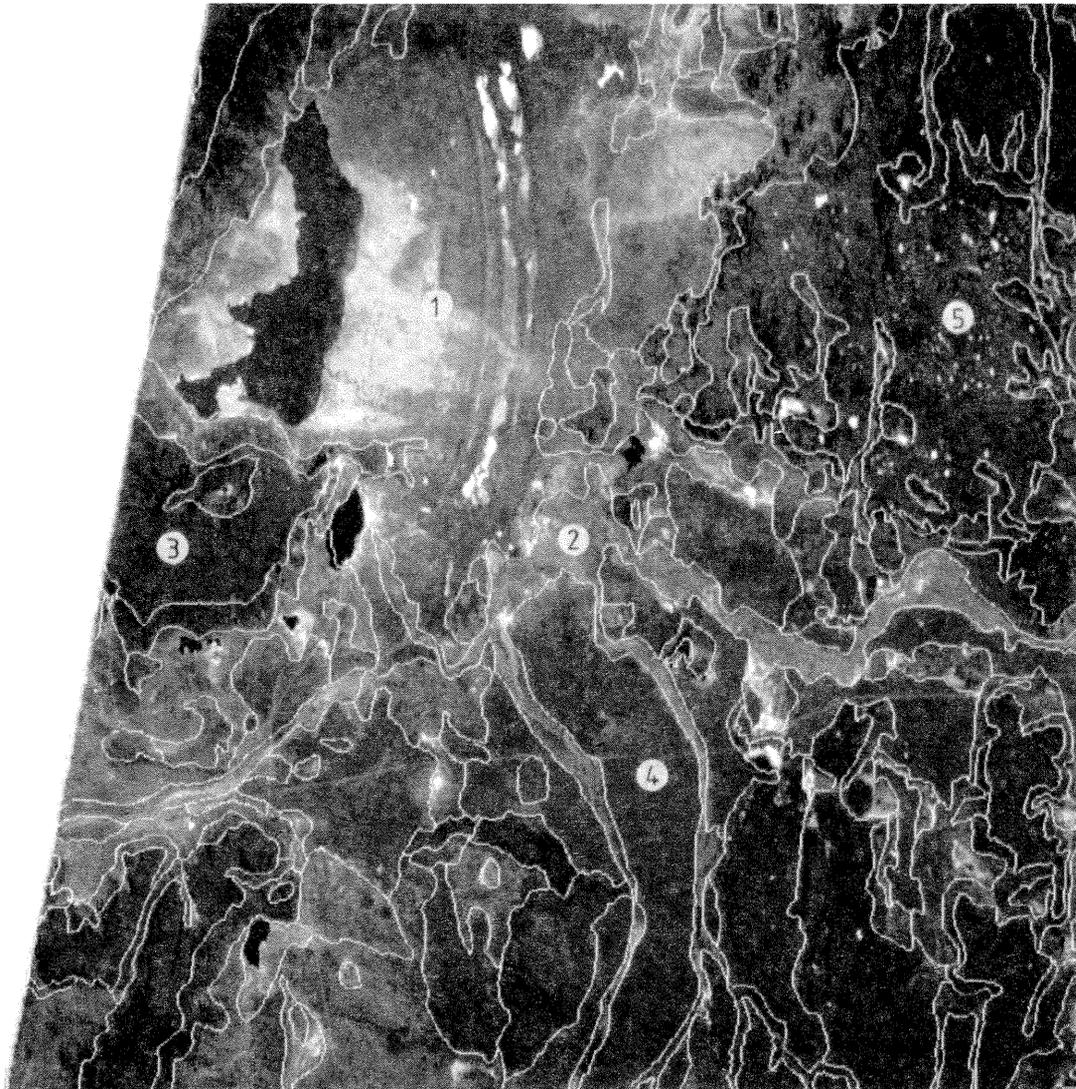


Fig. 6 Overlay LANDSAT MSS Imagery and Physiographic Map by SPECK et al. (1982) Geometry not corrected, scene approx. 50 km x 50 km, for numbers and comment see text

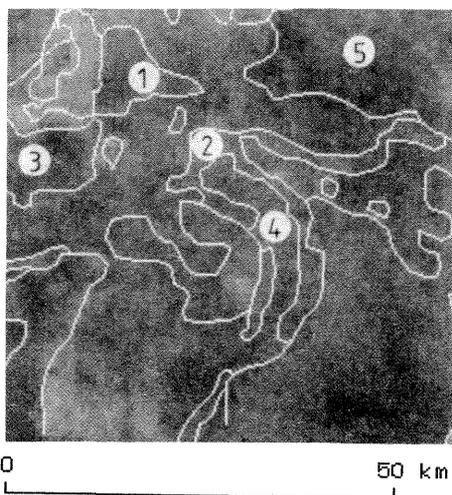


Fig. 7 Area Maquinchao-Jacobacci (Fig. 6) as recorded by NOAA (March 9th, 1987), bands 1, 2, 5 used for colour output

It turns out that multispectral classification would not allow to extract fully the information offered by LANDSAT MSS imagery for desertification monitoring. Interpretation of imagery by a skilled expert based on ground truth seems to be the best method for segmentation of object classes.

Small features may be very useful for the desertification expert and serve as an important indicator for degradation. This is studied in large scale like explained in Fig. 6. However, the project has to consider Patagonia as a whole.

Consequently, monitoring of desertification in Patagonia presents a lot of organisational challenges, because it refers to a very large area while individual plants may serve as indicators for the degradation process. Therefore the procedure „from large to small“ is applied: starting from intensively checked areas (like Jacobacci-Maquinchao) the knowledge acquired there - including ground truth - is used in the transects and from there interpolated for the whole country. This process represents a particular regionalisation scheme.

Fig. 7 gives the area Maquinchao-Jacobacci as recorded by NOAA. It is evident, that there exists a considerably higher level of abstraction than for LANDSAT MSS. The interpreted classes refer to the scheme given for Fig. 6, and without the basic knowledge from LANDSAT MSS and ground truth there is no chance for reliable interpretation of NOAA imagery.

Acknowledgments

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