COMPARISON BETWEEN VARIOUS REMOTE SENSING METHODS FOR ESTABLISHING THE STATE OF FOREST HEALTH

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The work in this research paper was divided equally among all the authors.

This present work is part of the "*Progetto di indagine sperimentale sul deperimento e sulla protezione delle foreste contro l'inquinamento atmosferico*" (Project for the experimental study of the deterioration of forests and their protection against atmospheric pollution) which was devised by the Emilia-Romagna Regional Government to carry out the European Council Regulation N° 3528/86 and the modifications instituted by E.C. Regulations N° 1696/87 and N° 2995/89. The general aim of the study is to devise (by means of images produced through remote sensing) a methodology for assessing the state of forest health which would exploit available photographs and not require special photographic missions.

This work aims to illustrate the problems faced and the results obtained in the second phase of the study which, proceeding from the conclusions of the first phase (Vignali *et al.* 1993, 1994), extends the comparison (with regard to both the scale of acquisition and the types of sensors) between the different remote sensing techniques which are available for determining the state of forest health.

To this end, a comparison was made between the results obtained from both small-scale (1:33.000) CIR photographic interpretation and DAEDALUS digital data processing tests and the results obtained over the course of the first phase of the project (CIR photogram photo interpretation at a scale of 1:10.000).

DAEDALUS digital aerial photographs (use was made of Istituto Geografico Militare - I.G.M. - material from the DAEDALUS 1990 acquisition campaign) were included as they were, by now, freely available on the market at a price considered not too exorbitant and they had been taken on the same occasion, using the same aircraft, as had the CIR 1:33.000-scale photographs. These data are extremely interesting because they promise a notably wider cognitive range of the territory from the

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radiometric point of view, and at the same time they are easily comparable with other types of acquisition.

The subject of investigation is the Boschi di Carrega Regional Park at Parma and the area surrounding it where the ground inventory of forest damage on 41 sample areas is under way and also where trials of aerial non-photogrammetric CIR small-scale (35mm) photography using ultra-light aircraft have been carried out.

According to the results obtained, the regional government will be able to verify which investigative methodology is the most suitable for use in other sections of the territory.

Introduction

The study is being carried out in the ambit of the Emilia-Romagna Regional Government's "*Progetto di indagine sperimentale sul deperimento e sulla protezione delle foreste contro l'inquinamento atmosferico (1991-1995)*" (Project for the experimental study of the deterioration of forests and their protection against atmospheric pollution). One of the phases in the project consists in the use of remote sensing to ascertain the phyto-sanitary conditions of the stands in six sample areas situated in four regional provinces. In this report we shall describe the evaluation of various remote sensing equipments and of differents interpretation methods on the Carrega Forest sample area.

Area of study

The study area includes the territory where the Boschi di Carrega Regional Park is situated, a belt of foot-hills in the Parma province of roughly 5,000 hectares altogether. The morphology in the northern part features a series of gently sloping terraces with a prevalently northern aspect, whereas to the south the landscape consists mostly of rolling hills of a decidedly marked nature, some of which subject to landslides and erosion.

The vegetation consists of oak forest (a mixture of cerris and durmast oak) alternated with chestnut groves and conifer reforestation. In the southern area, discontinuous forests of pubescent oak prevail.

Aerial photography

Two missions, using dissimilar aircraft and photographic equipment, were expressly undertaken in the area under study:

a) CIR small-format exposures: a mission was carried out on 31 August, 1991, in an ultra-light aeroplane equipped with a reflex camera of 35mm format, fitted with a lens of 50mm focal

length. The flight altitude was variable and the film employed was Kodak Aerochrome Infrared 2443, suitably cut for use with a 35mm camera. The photographs cover the area erratically and are limited to brief strips.

b) Conventional (large-format) photographs: aerial photography was undertaken on 6 September, 1991 with an aerial survey camera of a 23cm format, equipped with a lens with a focal length of 150mm. The approximate flight altitude was 1,800m a.s.l. and an area of 5,300 hectares was covered. In this case as well, the film employed was Kodak Aerochrome Infrared 2443. The resultant photographic material consists of slides at the approximate scale of 1:10,000.

These photographs allowed the drawing up of an inventory of the health of the stands based on the "Sanasilva" methodology.

Over the same sample area was tried out this remote sensing material available at I.G.M.:

1) Conventional CIR photographs at a scale of 1:33,000: on 13 June, 1990, exposures were made over the area under study from a LEARJET 25 I-BMFE aeroplane, fitted with an aerial survey camera of a 23cm format, complete with a lens having a focal length of 150mm. The exposures form part of a joint CIR/DEADALUS acquisition campaign which to date covers all of north and central Italy. With five photograms pertaining to two west-to-east strips, the area was entirely covered. The approximate flight altitude was 5,800m a.s.l., the meteorological conditions were characterised by slight mist, though visibility remained over 10 km. The film employed was Kodak Aerochrome Infrared 2443. The photographic material used consisted in 23cm prints on lactate base supports.

2) DAEDALUS acquisitions: exposures over the northern zone of the study area were made at the same time as the CIR photographs at the scale of 1:33,000, whereas, owing to the lack of optimum meteorological conditions for digital exposures over the southern part, the mission there was repeated on 23 June, 1990. The photographic conditions were the same as in the preceding paragraph. The sensor used was the multispectrum DAEDALUS ATM scanner with 12 scanning channels. Scanning speed was 12.5 scans per second (for both strips). The acquired data, registered in single bands, were recorded on HDDT tape.

	35mm CIR flight	Large-scale 23cm CIR flight	Small-scale 23cm CIR flight	DAEDALUS flight
Flight Dates	31.08.1991	06.09.1991	13.06.1990	15.06.1990, 23.08.1990
Flight Altitude	from 200m to 300m above ground level	1.800m (a.s.l.) absolute	5,800m (a.s.l.) absolute	5.800m (a.s.l.) absolute
Scale of exposures	1:1.000 (approx.)	1:10.000	1:33.000	12m pixel (max. resolution)
Meteo conditions	good	good	slight mist	slight mist, cloudy sky
Photographic equipment	Reflex Canon F1	WILD	WILD	DAEDALUS ATM
IFOV				2.5 millirad
Type of film	Kodak 2443	Kodak 2443	Kodak 2443	

Table 1. Technical data of aerial photographs

DAEDALUS data processing

Illustrated here below are the first results of the processing of digital photographs taken by the Sala Sistemi of the Italian Military Geographic Institute (I.G.M.) on behalf of the Emilia-Romagna Regional Government with the use of the airborne DAEDALUS multispectrum scanner. Processing was in collaboration with I.G.M. technicians who co-ordinated the informatics and the management of the operative systems and with forestry technicians of the Emilia-Romagna Region who dealt with the visual image interpretation and the validation of the data obtained.

The acquisitions were made band to band. Only those bands proving to be without scanning faults were used for interpretation (at least for the woodland area under study).

Geometrical corrections were effected to bring the Pixel from a rectangular shape (different for each point of acquisition and therefore extremely inhomogeneous) to lots of square, homogeneous Pixels. Algorithms are determined by aircraft speed, scanning speed and the relative flight altitude.

Atmospheric correction was not accomplished because there was a risk of it intensely falsifying the data (the image is excessively homogenised by it). This type of operation was deferred to a phase subsequent to interpretation when the quality of the angular resolution of the images (at that point already processed) will be required.

DAEDALUS ENTERPRISES model AADS 1268

Features

Channel 1	0.42-0.45 · m
Channel 2	0.45-0.52 · m
Channel 3	0.52-0.60 · m
Channel 4	0.60-0.62 · m
Channel 5	0.63-0.69 · m
Channel 6	0.69-0.75 · m
Channel 7	0.76-0.90 · m
Channel 8	0.91-1.05 · m
Channel 9	1.55-1.75 · m
Channel 10	2.08-2.35 · m
Channel 11	8.50-13.00 · m
Channel 12	8.50-13.00 · m

Table 2. Spectrum bands available with the DAEDALUS 1268 ATM scanner

As the IFOV (sensor aperture) is 2.5 milliradians at the working altitude of 5,760m a.s.l. (equivalent to the geometric resolution of about 2.5m every 1,000m of relative altitude), the average pixel had a ground resolution of 12 metres.

The aim of the present experimentation phase was:

- to assess the potential of the airborne multispectrum Scanner DAEDALUS in monitoring forest growth;
- to determine the best environments for its use and the best processing methodologies;
- to compare the results obtained with those deriving from the interpretation of the CIR exposures taken at a different scale.

To this end, various types of digital data processing were tried out with the aim of acquiring the band combination which best highlighted the different forestry typologies. A supervised classification was

then drawn up by means of the evaluation of a certain number of well-known training sets, allowing the discrimination of some of the main types of soil use and, within the woodland areas, that of the most recurrent forest typologies.

As regards the methodology, work was carried out in the following way:

- the extraction of the pixels relative to the area under study for each acquisition band and their collocation in single files;
- the checking of the quality of the single files and the selection of those actually of use;
- the geometrical correction of the datum;
- the theoretical study of the different bands and the research of the best ones for use in forestry
- the creation of synthetic bands (additive or subtractive synthesis between the bands) which better highlighted certain vegetative phenomena and which consequently better aided interpretation operations
- the study of the best images obtained and the search for areas with well-known vegetation which were easily identifiable for use as training sets in classification operations;
- the study of radiance values within the various training sets with the aim of identifying those values which were characteristic of just one interpretative typology;
- the use of automatic classification algorithms and the comparison of the results obtained both with those deriving from the operations of conventional photo interpretation and also with available thematic mapping;
- the extension of classification to the areas adjacent to the one under intense study and the evaluation of results.

A whole series of supervised classifications were tested, using a series of well-known training sets on different band combinations.

Comparison between the informative contents of the aerial photographs studied

35mm CIR aerial photographs (scale 1:1.000):
permit the assessment of the health of single trees. Even in coppices, sucker or stump foliage is almost always identifiable. They are not suitable for photo interpretation over homogeneous areas because of the high cost of effecting continual territorial coverage.

Possible uses:

- the accomplishment of interpretation keys in assessing the state of forest plant protection;
- evaluation of the health of single trees for ornamental greenery.

23cm CIR acrial large-scale photographs (1:1.000):

permit the assessment of forest health defined according to traditional forestry parameters. The state of health is expressed (Sanasilva methodology) for each polygon, attributing a value for presence and intensity of deterioration. They also permit the identification of species and structural characteristics even over limited surfaces.

Possible uses:

- large-scale forest planning;

- mapping of forest health status which defines the intensity and the distribution of forest decline.

23cm CIR aerial small-scale photographs (1:33.000):

the chromatic differentiation of stands in the study area does not appear adequate to assess the state of health over homogeneous surfaces because of the great fragmentation of the forest typologies present. Furthermore, it must be highlighted that, not having been expressly taken for the purpose, the photographs pertain to different periods of the year and therefore those features of health comparison are lacking. However, it cannot be excluded that, with districts which are more homogeneous from the morfological and vegetation points of view, the carrying out of a health analysis is possible on such areas.

The images allow the identification of the specific composition and the structural characteristics of the forest (type of management, density). The high quality in terms of angular and chromatic resolution, combined with the use of an adequate instrumentation, allows forest homogeneous areas to be defined which may even have reduced dimensions (½ hectare).

Possible uses:

- forest mapping at a medium scale (1:25.000);

- territorial planning on an intermediary level (plans for basins, district plans, etc.).

DAEDALUS acquisitions:

possess a radiometric informative contents which is superior to that of aerial photography (and angular resolution appears tolerable at the acquisition scale used - 1:33.000 - even though not comparable to that of photographs), but managing them turns out to be more complex and extremely costly hard- and software is needed to permit the optimal exploitation of their potential.

Considerable (and, for the moment, unresolved) problems arise in the interpretation phase on account of a shadow effect. This effect leads to complete confusion of radiance values, especially so in the bands most useful for highlighting vegetation emergences. Finally, the capacity of DAEDALUS to identify homogeneous areas, even if they are small, appears good where not disturbed by shadow effects.

This type of exposure permits guided, automatic classification to be carried out and facilitates gathering information as to the actual use of the soil. Distinction between broad-leaved trees and conifers is possible and the species can be identified at group level, but information of a geometrical nature is not provided.
It would not appear suitable for the study of forest health.

Possible uses:
- cartography of actual soil use (updating);

- territorial statistical investigation

COMPARISON BETWEEN THE INFORMATIVE CONTENTS OF THE AERIAL PHOTOGRAPHS UNDER STUDY

	35mm CIR photographs, 1:1.000 scale	23cm CIR photographs, 1:10.000 scale	23cm CIR photographs, 1:33.000 scale	DAEDALUS exposures
USE OF THE SOIL*	NR	X	X	X
FOREST				
Broad-leaved trees/Conifer	X	X	X	X
Height	X	X	NR	NR
Density	X	X	X	O
Kind of management	X	X	X	NR
Species (at the polygon level)	X	X	X	O
Species (at single plant level)	X	O	NR	NR
STATE OF HEALTH				
at polygon level	NR	X	O	O
at single plant level	X	X	NR	NR

Legend X = Detectable parameter

0= Parameter detectable in certain conditions

NR = Undetectable parameter

Table 3. Summarising table of the informative contents of use in forestry obtainable from the photographs under study.

* (forest, shrubbery, meadow, uncultivated, sowable, bare soil)

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