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JOINT RESEARCH CENTRE

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LANDSAT-2 SATELLITE FOLLOW-ON INVESTIGATION No. 28790
AGRICULTURAL RESOURCES INVESTIGATIONS IN NORTHERN ITALY AND SOUTHERN FRANCE
(AGRESTE PROJECT)

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Fifth Progress Report

28790

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January 1st – March 31st, 1977

COMMISSION OF THE EUROPEAN COMMUNITIES
JRC - Ispra Establishment

LANDSAT-2 SATELLITE FOLLOW-ON INVESTIGATION no. 28790
AGRICULTURAL RESOURCES INVESTIGATIONS IN NORTHERN ITALY AND SOUTHERN FRANCE

(AGRESTE PROJECT)

Fifth Progress Report

January 1st - March 31st, 1977

PART I
ACTIVITY PERFORMED ON THE ITALIAN TEST-SITES

LIST OF INSTITUTES AND ORGANISATIONS INVOLVED IN THE RESEARCH

• Biology Group - Ispra of Directorate for Science and Education	BGI
• Centro Applicazioni Tecnologie Avanzate - Napoli	CATA
• Ente Nazionale Risi - Mortara	ENR
• Istituto per la Geofisica della Litosfera - Milano	IGL
• Istituto Nazionale delle Piante da Legno - Torino	INPL
• Istituto di Patologia Vegetale dell'Università - Milano	IPV
• Istituto Sperimentale per la Cerealicoltura - Vercelli	ISC
• Istituto di Sperimentazione della Pioppicoltura - Casale Monferrato	ISP
• Joint Research Centre - Ispra	JRC

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SUMMARY OF THE ACTIVITY AND THE RELEVANT RESULTS

An experiment of atmospheric corrections of LANDSAT data has been made, applied to the flat water surface of lakes on test-sites no. 2. In this case the correspondance to the situation of rice areas on test-site no. 1, flooded during the sowing period, is evident. It has been found that the standard atmospheric correction procedure cannot be successfully applied to water targets if a better correlation of MSS data with radiance input to the LANDSAT satellites' sensors is not reached.
Furthermore it has been confirmed that the "six line effect" must be absolutely avoided unless some more sophisticated data handling techniques allow to subtract different amounts of path radiance for the six satellite detectors. This appears to be more evident for the TELESPAZIO data than for the NASA data.

Software has been prepared to allow interpreters' team at the JRC to perform automatically extensive quantitative comparison (pixel by pixel) between classification results and corresponding ground-truth. A program has been written to memorize on magnetic tapes the reference ground-truth data prepared on a geographical map form by the AGRESTE Institutes. This automatic comparison is made using a "performance matrix" procedure. Now it is possible to obtain a complete geographical color-video display of such performance matrixes allowing the location of correctly classified areas and the knowledge of different type of misclassification.

COPTRAN program for atmospheric corrections of scan angle influence on atmospheric path has been modified and completed.

These new tools have been applied to discrimination of rice varieties from airborne MSS data acquired on test-site no. 1 during the 1976 flowering period and to classification of planted poplar groves in the Po valley from satellite MSS data.

Six rice varieties were well recognized in proportions ranging from 65% to more than 80%.

The same techniques have been applied to classification of planted poplars groves from LANDSAT data: poplars are recognised with a precision of about 70%.

Correction of the airborne data from the atmospheric effects brings a noticeable improvement in the results, the "long-track" averaging procedure, applied to the mean and variance of the data being found suitable in this respect.

Some LANDSAT data processing and interpretation activity has also started for the test-area of the CHIAPPONA-form controlled by ENR (test-site no. 1). Some rice, maize and poplar areas have been identified using NMAPW techniques. Evolution of satellite data is being followed for the 1975 rice growing season.

1. Introduction

The activity reported here (January 1st - March 31st 1977) is a continuation of the preceding one, carried out by the Joint Research Centre, Ispra, on the Italian test sites, following the LANDSAT-2 launch, in collaboration with the Biology Group of the Directorate General for Science and Education and the Italian Institutes and Organizations in the framework of the LANDSAT-2 follow-on investigation no. 28790 (AGRESTE Project).

2. Waiting for supplemental LANDSAT-2 imagery of the Madagascar test site. Request for an extension of the AGRESTE investigation

A request was made to EROS Data Center by the AGRESTE PI Dr. S. Finzi on Febr. 2, 1977 for a listing of all the available scenes containing the AMBATONDRAZAKA area, even with cloud cover of up to 100% and whatever quality (see 4th PR, 2.5).

Unfortunately this last attempt to find almost one usable scene has given no positive result.

However, the importance of the African test site for the overall AGRESTE investigation is well known. Moreover a special effort was done by the EC Directorate-General for Aid to Development (DGVIII) to obtain from the Madagascar authorities a consistent ground truth (in particular an important aerial photographic coverage.

Now the AGRESTE PI hopes to obtain usable data as a result of coverage of the Madagascar area by LANDSAT-2 requested and accepted by NASA for the period of Febr. and April/May, 1977 (see 4th PR, 2. 6).

In this perspective, a six-months extension of the AGRESTE investigation is being officially requested to LANDSAT Investigation Manager, Dr. R.D. Price.

This will also allow the AGRESTE COTS to improve the results being obtained on some medium-term objectives. In particular, some applications of computer-aided classification methods for European renewable resources inventory are expected to take advantage of the requested extension.

3. Activity performed over the relevant period

3.1. Research objectives and task distribution

During the fifth research period of the AGRESTE investigation, activity has been directed mainly towards the following objectives:

a) Computer-aided interpretation of airborne and satellite scanner data.
   Discrimination of rice varieties (test sites no. 1):
   Classification of planted poplar groves in flat areas (test site no. 3).

b) Digital realization of discrete ground-truth mapping.
c) Applicability verification of some atmospheric correction algorithms, (test site no. 2).

Task distribution is summarized in Table 1.

– TABLE 1 : TASK DISTRIBUTIONS AMONG THE AGRESTE–CO–INVESTIGATORS

	Specific Objectives	ENR	INPL	ISC	ISP	JRC
Rice investigation	Determining influence of atmospheric path on spectral signature and correcting for it					- Radiometric measurements - Data processing and interpretation
Rice investigation	Ground-truth preparation	Improving, producing and/or interpreting partial maps (satellite and aircraft)		Preparation of reference maps		Digital realization of discrete ground-truth mapping
Forest invest.	Ground-truth preparation		Interpretation of photographic maps		Preparation of reference maps	Digital realization of discrete ground-truth mapping
Aircraft and satellite data processing and interpretation	Software preparation					– Performance matrices. – Correction of scan angle influence on atmospheric path
Aircraft and satellite data processing and interpretation	Classification and inventory	Aid to interpretation				Computer-aided interpretation of airborne scanner data. Discrimination of rice varieties
					Aid to interpretation	Classification of planted poplar groves in flat areas
		Aid to interpretation				Identification of some controlled test-fields on the Chiappona-farm area

3.2 Application experiment of atmospheric corrections

In the course of the AGRESTE investigation a technique for the measurement of atmospheric parameters (path radiance and transmittance) was set up (see 1st QPR). In addition many measurements of these parameters from fields were performed at time of LANDSAT satellites' cross over of the Italian test site no. 1 (see 2nd QPR, 3.2.3).

Because the classification procedure for rice and poplars used at the JRC Ispra does not provide for the moment the use of these measurements, it was decided to check the possibility of applying atmospheric corrections to the flat surface of lakes where the contribution of path radiance due to Mie-and-Raleigh scattering in the atmosphere is important. /1/.

The correspondance to the situation of rice areas flooded before and after sowing is evident.

Computer compatible tapes from the Italian tracking station Telespazio with LANDSAT MSS data from March 29, and June 9, 1976 were processed using level slicing and simple ratioing (Channel 4/Channel 5) techniques. The maps produced without atmospheric corrections showed a distinct "6 line effect" with signature repetition in every 6 lines but large jumps in values between adjoining lines.

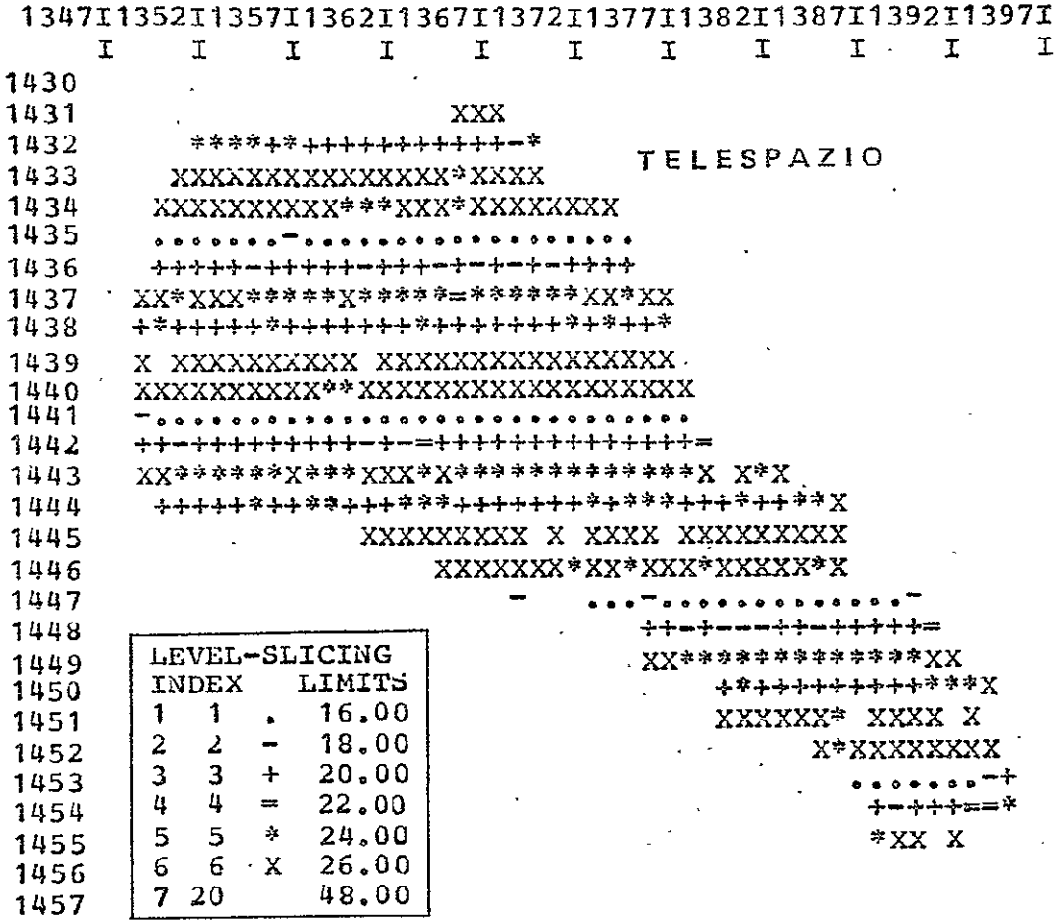
This effect, which does not correspond to a physical property of the observed surface, is more and more enhanced when path radiance is subtracted in a fixed amount regardless of the 6 detectors per band.

A comparison between CCTs from NASA and from Telepsazio containing the same LANDSAT MSS data (Sept. 13, 1975) was made. Differences in grey level maps of the three considered lakes were striking. An example is shown in Fig. 1 where the two grey level maps for lake Monate are given.

The mean values and standard deviations were calculated on uncorrected pixels from the two computer tapes for the same regions in the middle of the three lakes. The results are given in Table 2.

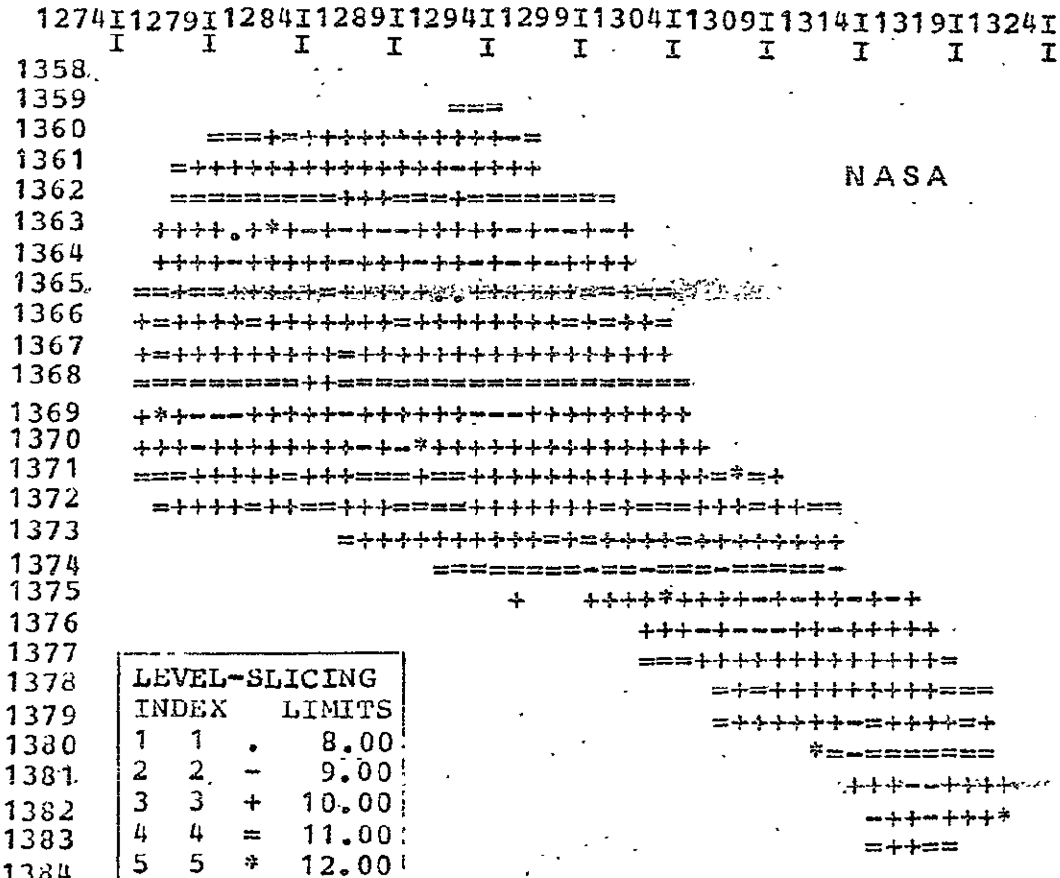
TABLE 2:

LAKE	NUMBER OF PIXELS	M S S 4				M S S 5			
		Mean value		Standard deviation / Mean value		Mean value		Standard deviation / Mean value	
		NASA	Telespazio	NASA	Telespazio	NASA	Telespazio	NASA	Telespazio
Varese	640	13.6	29.1	0.066	0.134	9.9	21.1	0.071	0.109
Comabbio	63	10.7	24.1	0.065	0.158	8.0	17.0	0.163	0.182
Monate	240	9.1	20.8	0.066	0.183	5.2	13.4	0.135	0.172
		M S S 6				M S S 7			
Varese	640	6.4	14.3	0.156	0.175	0.0	3.3	-	0.545
Comabbio	63	8.8	16.4	1.307	0.908	2.9	9.4	2 517	2.28
Monate	240	3.0	10.1	0.333	0.277	0.0	2.7	-	1.111



LEVEL-SLICING

INDEX			LIMITS
1	1	.	16.00
2	2	-	18.00
3	3	+	20.00
4	4	=	22.00
5	5	*	24.00
6	6	X	26.00
7	20		48.00



LEVEL-SLICING

INDEX			LIMITS
1	1	.	8.00
2	2	-	9.00
3	3	+	10.00
4	4	=	11.00
5	5	*	12.00
6	20		24.00

Fig. 1 : Comparison between grey level maps of Lake Monate from September 13, 1975. The upper map shows the Telespazio rendition and the lower map the NASA rendition

The standard deviation from the mean value is higher on the Telespazio tape in MSS 4 and, to a smaller degree in MSS 5, than on the NASA tape. These discrepancies may be due to the calibration method used by Telespazio where the compensation for radiometric errors is based on a statistical analysis of the scene video data. This method results in a poor correlation of MSS data with radiance input to the sensors and does not reduce the six line effect.

This effect is even more readily observed after the atmospheric corrections in which the path radiance is subtracted from the MSS recorded radiance.

As a first conclusion it may be stated that atmospheric corrections cannot be applied with success to water if a better correlation of MSS data with radiance input to the sensors is not reached. Furthermore the six line effect must be avoided unless a more sophisticated data handling allows the subtraction of different path radiances for the six detectors per band.

3.3 Satellite and Aircraft data processing and interpretation

3.3.1 Software development

3.3.1.1 Digital realization of discrete ground-truth mapping
In order to allow extensive quantitative comparison pixel by pixel between results of classification and corresponding ground-truth, a program has been written and implemented to memorize on magnetic tape the reference ground-truth data reported on a geographical map.

The procedure adopted is the following:

a) the reference map is gridded into discrete elements corresponding to the pixels of the LANDSAT satellite. Gridding is obtained by following an iterative comparison process between reference map and corresponding LANDSAT image aimed at establishing the correct direction of satellite scanning on the map and the exact location of some "one pixel" marks both on the map and on the LANDSAT digital scene;
b) the zones to be reported are then obtained from the corresponding discrete digital contours (given as input) by running a contour-follower routine. They can be visualized either on a COMTAL Color System or by means of a conventional line-printer output.

The overall accuracy of the above mentioned procedure is crucial as far as the reliability of the classification results is concerned, owing to the relatively small dimensions of most individual areas to be classified (down to one pixel in extreme cases).

3.3.1.2 Performance matrices
Using the digitalized ground-truth obtained using the procedure described in 3.3.1.1, a program was written to obtain automatically a quantitative comparison between classification results and corresponding ground-truth. This comparison is made using a

classical "perforöance matrix" (square or rectangular) where each row corresponds to a "truth" class on ground and each column corresponds to a class given by computer classification algorithms.

Outputs available from the performance matrix are twofold. In fact, each matrix element may give either:

a) the total number of pixels of a certain category on the ground (horiz.) which are classified in a certain manner (vert.), or resp.
b) the corresponding percentage value of each "truth" category.

In order to evaluate the accuracy of total acreage estimation for the area considered, the ratio

$$\frac{\text{number of pixels classified}}{\text{number of pixels actually present on ground}}$$

is given as supplementary information for each class. These data are reported in the last row of performance matrix. Some application examples are reported in the following sections.

Optionally the program gives a complete geographical display of the performance matrix allowing the location of correctly classified areas and the knowledge of the different types of misclassification. This is obtained by translating pixels for each matrix element into the COMTAL screen through a color-coded representation.

3.3.1.3 Correction of scan angle influence on atmospheric path
As the total scan angle of the Bendix M^2S scanner is 100°, it is well known that the variation of the thickness of the atmosphere between the scanner and the ground along a scan line causes a systematic variation in the data acquired, due to the corresponding variation in path radiance and transmittance. The COPTRAN reformatting program has been extended to include three correction procedures, based on the assumption that, in the absence of the above mentioned atmospheric effect, the mean and the variance for each channel over the whole flight line along a constant scan angle is the same for all scan angles. The COPTRAN routine computes in a first pass for each channel the mean value and the variance over five pixel-wide columns. Mean and variance are then smoothed over the scan line through an eight degree, and a four degree polynomial fit. In a second pass, a linear transformation computed from the fitted curves is applied to each group of five columns of the imagery data such that the mean, and optionally the variance, over the whole group is about the same for each group of columns.

3.3.2 Computer-aided interpretation of airborne scanner data

3.3.2.1 Discrimination of rice varieties

3.3.2.1.1 Characteristics of the data
The data were acquired on August 7th, 1975, between 9.11 and 10.32 o'clock in the morning by a Bendix M^2S scanner, August 7th being a date on which the various rice varieties were expected to

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be in the flowering stage (see 4th QPR, 5.4.3.1). The data from channels 1, 2 and 10 were not used, however, due to the unacceptable noise level. The resolution of the data at the altitude of 5000 feet is 3.8 m. The flight was done in the region to the South of the town of Mortara; the strip of data processed here covers a zone approx. 3 km^2 in area where six rice varieties are present.

3.3.2.1.2 Ground-truth preparation
The work was done in collaboration with ENR. The final document (Fig. 2) was prepared using the program described in 3.3.1.1.

Due to the high resolution of airborne scanner data, there is no difficulty in finding correspondance between details on the ground and on the scanner image in this case.

All the rice fields present in the strip were not characterized from the point of view of rice variety; the black parts of Fig.2 (apart from roads and lanes in the fields), correspond to fields containing unidentified varieties or mixtures of varieties, which often occur in the studied zone. All the black parts of Fig. 2, including this time roads and lanes, visible as straight lines, are then considered as uncharacterized areas on the ground-truth map. The "other" class has also been left in black.

3.3.2.1.3 Classification methodology
Two methods of classification were used: maximum likelihood method (ML) and modified euclidean distance method (MED). In each case the classification was exhaustive, including also the zones uncharacterized on the ground-truth. No membership threshold was applied to any of the classes and no point was therefore left unclassified. The training of the algorithms was done, as above, on small portions of the ground-truth classes. Care was taken that the statistical distributions in the training sets be nearly unimodal although training sets of the same ground-truth class could present noticeable differences between the respective distributions. Better global results were obtained, however, with the ML method by merging together all the sub-distributions of the same class than by processing such "sub-classes" separately. The opposite was true, on average, with the MED method, class A and class M particularly were each divided into three sub-classes.

3.3.2.1.4 Atmospheric corrections
The data were corrected for atmospheric absorbtion using the COPTRAN program described in 3.3.1.3.

3.3.2.1.5 Principal component analysis
A linear feature selection has been tested by principal component analysis, following Borden et al. /2/. In other words, the linear transformation applied to the data is constructed on the criterion of minimum information loss in the sense of the variance of the data.

The transformation matrix is formed by a suitable number (depending on the data reduction desired) of eigen vectors of the variance-covariance matrix calculated over the whole area studied.

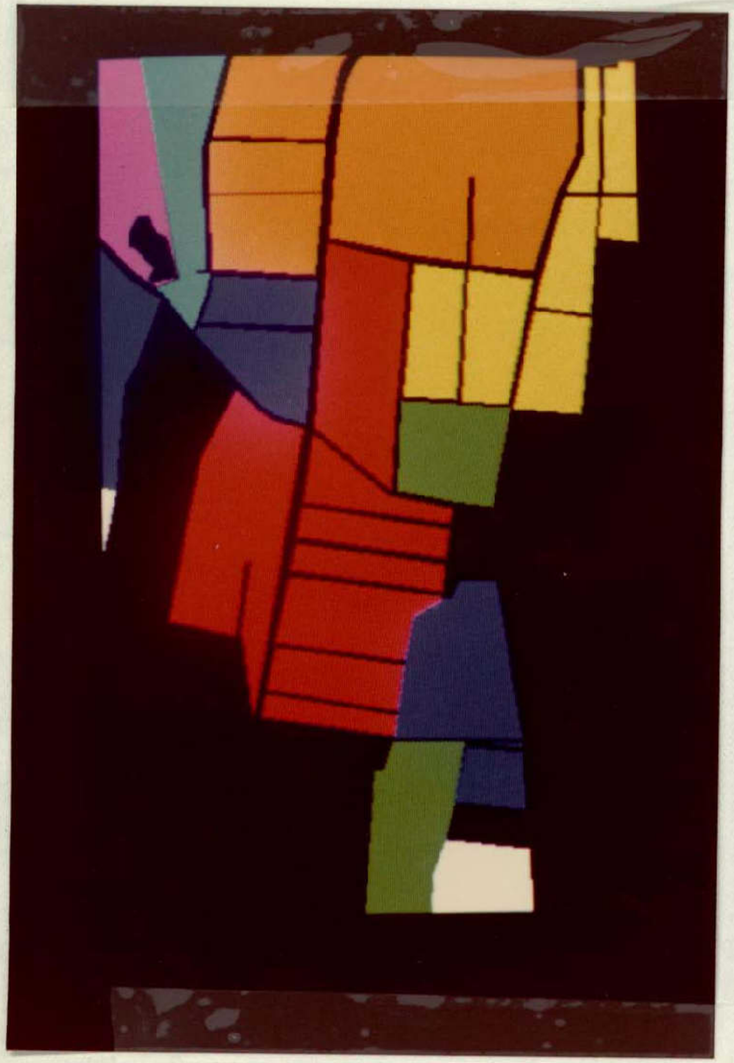

Fig. 2 : Digital ground-truth photographed from COMTAL Screen; color-coded as follows: G: green, B: red, A: blue, MR: white, M: yellow, C: orange, RC: light blue, RO: pink, O and NC: black

Fig. 3 : Results of ML classification; color-coded as Fig. 2

3.3.2.1.6 Outline of the results

The complete results are displayed in Tables 3 to 8, where UC means uncharacterized areas on the ground truth. They will be briefly commented on here.

The best result was obtained, as expected, with the ML method using all the 8 channels available (Table 3).

TABLE 3: RICE VARIETIES - PERFORMANCE MATRIX FOR M.L. 8 CHANNELS

	G	B	A	MR	M	C	RC	RO	O
G	71.4	7.9	9.8	0.0	2.4	0.2	2.5	0.2	5.4
B	2.9	76.4	1.2	0.1	3.1	1.7	0.4	0.3	13.9
A	11.3	1.3	66.8	0.0	3.9	0.2	3.2	0.9	12.3
MR	0.1	0.0	0.4	83.5	2.2	0.0	0.1	0.0	13.8
M	0.2	0.0	0.2	0.1	80.1	0.0	0.1	0.0	19.2
C	0.8	10.3	0.3	0.0	1.0	64.7	14.7	2.5	5.6
RC	0.9	1.3	4.5	0.0	1.3	0.5	78.3	10.2	3.0
RO	0.2	1.7	8.8	0.0	1.2	0.1	26.0	51.2	10.8
O	0.5	1.2	0.1	1.6	2.8	0.1	0.1	0.1	93.5
UC	2.0	12.0	3.4	0.4	13.8	3.6	1.9	0.6	62.3
Total classed/total present	105	97	83	89	108	68	210	84	

Meaning of symbols: G: Gretna, B: Balilla Grana grossa, A: Arborio, MR: Wet Meadows, M: Corn, C: Carnaroli, RC: Rocco, RO: Romeo, O: "Other" i.e. not vegetation, UC: uncharacterized.

It is seen that the discrimination is generally very good between rice varieties on the one hand, and between rice and other vegetal species on the other hand. The percentage of ground-truth classified as such varies from 65 to 83%, apart from variety RO.

The feature selection by PC analysis from 8 to 5 dimensions has very little effect on the results (Table 4), but the calculation time is decreased from 29 min. to 18 min. (CPU time - 134320 pixels processed); the fraction of the total variance conserved in the transformation is 99.2%.

TABLE 4 : RICE VARIETIES - PERFORMANCE MATRIX FOR M.L. 5 DIMENSIONS

	G	B	A	MR	M	C	RC	RO	O
G	69.1	7.4	11.5	0.0	3.0	0.6	3.1	0.2	5.0
B	2.9	74.4	1.2	0.0	4.4	2.7	0.4	0.3	13.6
A	15.2	1.0	63.7	0.0	6.4	0.2	2.8	0.9	9.7
MR	0.0	0.0	0.5	85.4	3.9	0.0	0.0	0.0	10.1
M	0.3	0.0	0.3	0.2	78.0	0.0	0.1	0.0	21.1
C	1.1	11.7	0.4	0.0	1.2	62.4	14.6	2.8	5.7
RC	2.1	1.3	5.4	0.0	1.3	0.6	76.3	10.3	2.5
RO	0.2	1.5	11.9	0.0	1.2	0.2	27.0	47.9	9.7
O	1.1	1.4	0.4	1.4	5.4	0.2	0.2	0.1	89.7
UC	2.5	11.9	3.6	0.4	17.6	4.0	2.0	0.5	57.4
Total classed/total present	111	96	82	90	117	67	204	83	

The raw classification results are displayed in Fig. 3 for this last case. It is seen that the ground truth should be modified in order to contain all the roads and lanes actually present, which would probably improve the percentage of well classified pixels on the diagonal of the performance matrices. It is also seen that the uncharacterized rice fields (in black) on the ground truth are mainly classified as mixtures of varieties with the exception of zones where rice was not recognized. It must be said in respect of this that other varieties, not identified on the ground-truth, are present in the same region and were not sampled here.

Tables 5 and 6 contain the results obtained with the MED method. It will be seen from what has been said on the MED scheme in section 1, that the linear transformation defined by PC analysis, but retaining the dimensionality of the space (i. e. 8 dimensions), should improve the results of the method because it has a tendency to decouple the variables as the global variance-covariance matrix of the whole area becomes diagonal. Table 6 presents the results for such a procedure and the comparison with Table 5 is conclusive. The results are not as good as those obtained with ML, especially for varieties C and RC, but the calculation time is reduced from 29 min. (or 18 min.) to 5. 5 min.

TABLE 5 : RICE VARIETIES - PERFORMANCE MATRIX FOR M.E.D. 8 CHANNELS

	G	B	A	MR	M	C	RC	RO	O
G	46.3	10.3	19.9	0.0	7.0	1.6	10.4	0.0	4.4
B	2.1	73.4	0.7	0.0	2.7	11.6	0.8	0.1	8.6
A	20.8	4.4	55.3	0.2	6.5	0.3	2.5	2.9	7.1
MR	0.1	0.0	0.2	74.3	5.5	0.0	0.0	0.0	20.0
M	1.9	14.8	1.0	0.3	57.7	0.1	0.0	0.0	24.1
C	2.7	28.4	1.2	0.0	1.6	46.4	12.4	0.1	7.1
RC	1.4	9.5	26.6	0.0	1.0	0.6	51.3	8.6	1.0
RO	0.9	20.5	36.4	0.0	0.8	0.3	15.7	24.2	1.2
O	0.5	5.7	0.5	10.5	11.1	0.8	0.3	0.0	70.7
UC	3.0	19.2	3.6	2.1	22.5	5.5	1.1	0.2	42.9
Total classed/total present	103	132	95	103	103	61	174	45	

TABLE 6 : RICE VARIETIES - PERFORMANCE MATRIX FOR M.E.D. 8 DIMENSIONS AFTER P.C. TRANSFORMATION

	G	B	A	MR	M	C	RC	RO	O
G	61.1	6.6	13.0	0.0	3.5	0.1	0.8	0.1	14.9
B	1.9	65.8	0.5	0.0	4.6	1.1	0.3	0.1	25.8
A	13.4	1.8	60.4	0.0	3.9	0.0	2.0	0.4	18.1
MR	0.3	0.0	0.2	68.2	0.7	0.0	0.0	0.0	30.6
M	0.2	3.2	1.9	0.0	69.3	0.0	0.0	0.0	25.4
C	1.4	23.5	0.5	0.0	2.2	43.4	10.9	0.8	17.2
RC	1.5	2.7	20.8	0.0	0.7	0.1	56.7	9.9	7.5
RO	1.1	5.4	26.8	0.0	0.7	0.0	20.1	29.8	16.0
O	0.2	1.8	0.3	0.4	1.6	0.0	0.0	0.0	95.5
UC	2.3	15.1	3.4	0.2	10.5	2.3	0.7	0.3	65.3
Total classed/total present	98	104	89	70	100	45	150	48	

All the results commented on up to now were obtained after performing the atmospheric correction applied to both mean and variance of the data. Table 7 contains results with ML method, 5 dimensions, without atmospheric correction, which compare with Table 4 in a very conclusive way, especially for varieties C, RC and RO located partly or entirely, towards the edge of the data strip.

The correction was applied only on the mean for the results displayed in Table 8 and the effect, although limited to second order, is however noticeable when comparing Table 8 with Table 4.

TABLE 7 : RICE VARIETIES - PERFORMANCE MATRIX FOR M.L. 5 DIMENSIONS WITHOUT ATMOSPHERIC CORRECTIONS

	G	B	A	MR	M	C	RC	RO	O
G	61.4	6.7	6.8	0.0	4.6	1.4	14.1	0.9	4.0
B	8.7	55.9	1.4	0.0	4.3	18.0	0.4	0.1	11.2
A	6.3	3.5	64.5	0.1	4.1	0.4	6.0	4.5	10.6
MR	0.2	0.6	0.3	87.0	1.7	0.0	0.0	0.0	10.3
M	0.4	2.4	20.0	0.0	72.8	0.0	0.2	0.1	4.1
C	2.6	30.6	3.5	1.1	15.4	29.3	0.6	0.0	16.8
RC	18.6	0.0	3.3	0.0	10.4	3.7	41.6	0.4	22.1
RO	22.6	0.0	25.2	0.0	1.7	0.0	3.7	15.7	31.1
O	7.2	6.0	0.1	2.9	4.4	0.4	0.3	1.0	77.5
UC	2.8	19.7	6.7	0.8	21.1	8.4	2.4	0.7	37.2
Total classed/total present	134	104	110	108	145	51	102	37	

TABLE 8 : RICE VARIETIES - AS IN TABLE 7 BUT ATMOSPHERIC CORRECTIONS ON THE MEAN ONLY

	G	B	A	MR	M	C	RC	RO	O
G	69.9	9.7	9.8	0.0	3.3	1.0	2.2	0.2	3.8
B	4.4	75.2	0.7	0.0	4.8	6.9	0.6	0.4	7.1
A	16.1	2.9	59.7	0.1	7.5	0.3	3.5	4.6	5.4
MR	0.2	0.3	0.3	86.9	2.9	0.0	0.0	0.0	9.4
M	1.0	0.2	0.7	0.2	81.5	0.0	0.1	0.0	16.1
C	1.8	14.0	0.2	0.0	0.9	66.9	12.8	0.3	3.1
RC	3.6	1.5	12.2	0.0	1.0	1.3	68.1	11.7	0.7
RO	1.0	6.1	22.0	0.0	1.9	0.7	36.9	30.0	1.4
O	2.1	3.5	0.3	1.8	6.7	0.7	0.5	0.1	84.3
UC	4.2	18.0	2.8	0.1	17.2	5.1	2.1	1.0	49.5
Total classed/total present	125	105	81	91	122	76	201	65	

3.3.3 Computer aided interpretation of MSS LANDSAT data

3.3.3.1 Classification of planted poplar groves in flat areas
The results already given in the preceding QPRS on poplars were improved using the techniques of quantitative comparison described in 3.3.1.2.

3.3.3.1.1 Ground-truth preparation
The ground-truth reference document was set up by ISP from an infrared aerial coverage, scale 1:10,000, made in August 1975 along the Po river at the level of the town of Valenza, about 100 km downstream from Turin (see 3rd QPR). The zone has an acreage of about 45 km^2.

ISP's researcher divided poplar groves into four classes:
- groves of one year;
- young groves (age 2 - 3 years) with less than 25% ground coverage;
- intermediate groves (age 4 - 6 years) with 25 - 75% ground coverage;
- adult groves (age 6 - 7 years and more) with over 75% ground coverage.

The poplar groves were then plotted in two comprehensive classes on the available U.T.M. map, scale 1:25,000:
- class 1 grouping all the young groves with ground coverage up to 25%;
- class 2 grouping intermediate and adult groves with ground coverage over 25%.

The global estimation error at this stage corresponds to 2 - 3% of the groves'acreage.

This ground-truth was then digitalized by the JRC. The corresponding computer map is represented in Fig. 4.

3.3.3.1.2 Classification methodology
The training sets were determined after a preliminary clustering of the data of the whole area using euclidian distance between points as similarity measure/3/, in order to bring out suitable clusters of pixels in the sense of uniformity and geographical location. They were then cleaned of marginal or anomalous points so that they would exhibit unimodal or nearly unimodal distributions. The training sets retained for poplars both belong to class 2 mentioned in 3.3.3.1.1. It was impossible to retain training sets for class 1 because the insufficient ground coverage - owing to the variability of the ground conditions - causes dispersion in the data and hence in the classification results. Training sets were also determined for unidentified but homogeneous clusters outside the poplar groves and for the Po river, so that an exhaustive classification of the area became possible by using one class "poplars", one class "water" and three unlabelled homogeneous classes.

The classification methods used were the "maximum likelihood" (ML) scheme as developed by Borden et al./2/ and the "modified euclidian distance" scheme (MED) which were both run without any threshold for the classes.

3.3.3.1.3 Outline of the results
They are shown in Table 9 and 10, some of them are displayed in Fig. 5. Tables 9 and 10 are the so-called "performance matrices" between ground-truth and classification for ML and MED methods. In the present case the poplar classes 1 and 2 were classified into a single poplar class for the reasons stated in section 3.3.3.1.2.

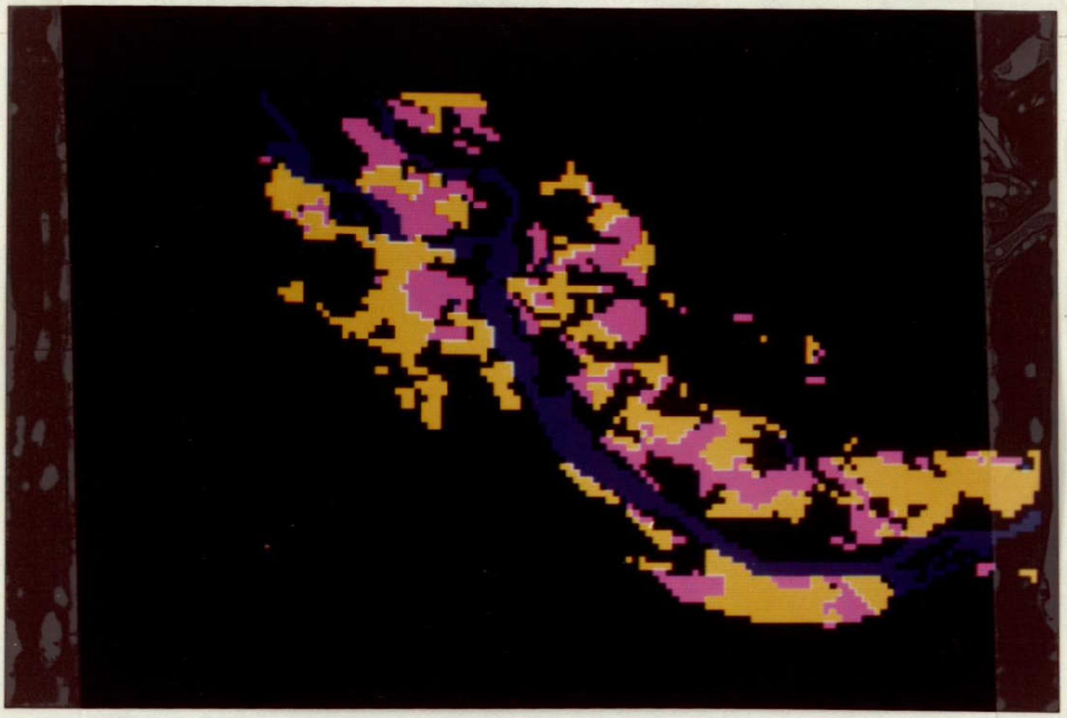

Fig. 4 : Digital ground-truth of planted poplar groves. Po river and water: blue, poplars class I (> 75% coverage): yellow, poplars class II (<75% coverage): pink

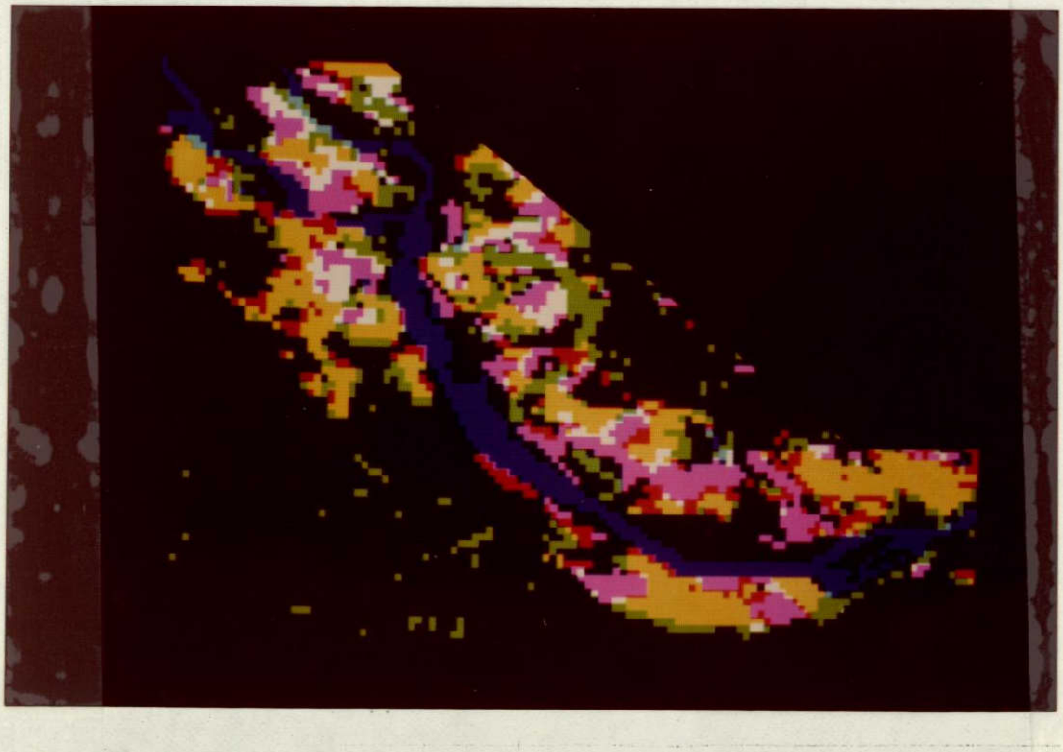

Fig. 5 : Display of performance matrix for poplars (ML classification). Water: blue, poplars I recognised as poplars: yellow, poplars I not recognised: red, poplars II recognised as poplars: white, poplars II not recognised: pink, other items misclassified as poplars: green

Table 9 : Poplars performance matrix for M.L. method

G.T. \ Results	Water	Poplars	Others
Water	76.9	4.1	19.1
Poplars class 1	2.5	27.4	70.1
Poplars class 2	0.6	70.4	29.0
Others	4.5	10.7	84.8
Total classed/total present	125	83.6	104

Table 10: Poplars performance matrix for M.E.D. method

G.T. \ Results	Water	Poplars	Others
Water	78.9	3.9	17.2
Poplars class 1	2.7	24.4	72.9
Poplars class 2	0.6	66.6	32.7
Others	4.9	8.9	86.2
Total classed/total present	131	75.3	106

A study already done, partly over the same zone, showed that by merging together three suitable LANDSAT scenes (June 15th, July 3rd and September 13th, 1975), it was possible to recognize the older poplar groves (class 2) with an accuracy better than 80% and to discard the younger groves classified within the single poplar class almost completely. This discrimination is important because the older class (from 4 years old) contains all the wood available each year for industrial needs.

As the computer procedure was available in the meanwhile for ground-truth construction and overlay, a more accurate study was undertaken with the "best" among the three scenes, i.e. June 15th 1975, in order to see the limits of single scene processing for this problem.

The trends of the results are very similar for both ML and MED methods. About two thirds of class 2 poplars are classified as poplars while only a quarter of class 1 is recognized. Misclassifications occur also between poplars and water but this is due almost entirely to difficulty in properly separating the Po river from the neighbouring poplar groves on the discrete ground-truth document (it is recalled that the J.F.O.V. of LANDSAT is about 80 x 80 m^2).

The class labelled "others" collects the three unidentified homogeneous classes referred to in section 3.3.3.1.2.

The comparison of the two methods shows that the ML scheme is somewhat better but has the drawback of much larger computing time (25 s CPU time instead of 10 s for MED, for classifying 9600 four-dimensional vectors into five classes, with an IBM 370/165 computer).

3.3.3.2 Classification of some controlled test areas

The activity herein reported deals with some LANDSAT-2 imagery interpretation being made specifically for the CHIAPPONA-farm area controlled by ENR (test site no. 1). Four scenes were taken into consideration. The two first scenes are on Telespazio tapes (30. 04. 75 and 06. 06. 75), while the two last ones on NASA tapes (03. 07. 75 and 13. 09. 75). For each scene a subset covering the region of MORTARA has been made. The four subset grouped together on a single tape are compatible with the COMPTAL unit. A copy on disk was also made allowing to be used by means of the "interactive system" (see 1st QPR).

3. 3. 3. 2. 1 Identification of rice, maize and poplar areas
A level slicing technique, for channel 7, (program NMAPW) has been used to obtain a "visualisation" of the total area. Thus, for each scene, the rice plots taken into account during the 1975 radiometric measurement campaign, have been identified from the investigated area. It has been necessary to group the measurement points, for scale reasons. Finally 8 groups of rice plots, roughly homogeneous, have been located.

The identification has been made by means of an aerial photo coverage of August 1975 on one hand and on the other hand by aerial photos made from a helicopter during the same period (see 2nd QPR, 3. 2. 3).

This work has been performed on the 03. 07. 75 scene, the first one available, then transferred on the others. Some difficulties arose for the Telespazio tapes (30. 04. 75 - 06. 06. 75); a geometric correction has been necessary, in order to allow superposition with the NASA tapes (MAPEDIT program).

Added to the 8 rice plots mentioned above, 4 large rice areas (100 pixels each, on an average), as well as 13 "non rice" areas (maize and poplar) were identified. Their location has been made by means of the 1975 aerial photo coverage.

3. 3. 3. 2. 2 Data processing and interpretation
Two directions have been followed: on one hand the classification of rice and other surrounding vegetal species; on the other hand the analysis of the rice plots' "spectral evolution", from March to September 1975.

3. 3. 3. 2. 2. 1 Classification of rice cultivated areas
Statistical analysis has been performed on the 25 training areas (STATS program) to obtain in the four channels: mean value, standard deviation, variance- covariance matrix, correlation matrix and eigen-vectors. Moreover, for the first 8 plots the values for each pixel in the four channels have been collected. Finally the data in bytes have been transformed into mw/cm^2-sec, in order to minimize the differences between NASA and Telespazio data sets.

Afterwards different methods are being used, to investigate the four scenes available:
- level-slicing, for channel 7;
- maximum likelihood classifier (PARAM D program): different sets of training areas have been tried;
- channels ratio. In particular the "extended ratio" (Maptel program).

No correction for atmospheric effects has been applied, up to now.

For each classification the results have been compared to the "ground-truth" map provided by E. N. R. (percentage of rice cultivated areas over a certain zone) (see 3rd QPR).

This work, completed for the 03. 07. 75 scene, is in progress for the other three.

3. 3. 3. 1. 2. 2 Evolution of spectral signals
The evolution of the 25 test areas has been followed from March to September 1975
- variation of response in channel 7;
- variation of the ratio channel 7 / channel 5;
- variation of the ratio channel 6 - channel 5 / channel 5 - channel 4.

No correction for atmospheric effects has been made up to now.

Interpretation of the relevant curves will be made over the considered period by means of comparison with the agronomic ground-data collected on the CHIAPPONA-farm area by ENR.

Moreover, the percertages of response per channel has been used to try to characterize rice and non-rice training areas: by means of the respective "weights" of channels 6, 5 and 4 in the total signal (4 + 5 + 6).

Finally some capabilities of the image processing unit (COMTAL) have been tested (i. e. superposition, for a single day, of the signals on three channels, superposition of three different days for a single channel).

List of references

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/2/ Borden F.Y., Applegate D.N., Turner B.J., Lachowski H.M., Merembeck B.F., Hoosty J.R., "Satellite and Aircraft Multispectral Scanner Digital Data Users Manual", ORSER-SSEC Techn. Rep. 1. 75)1975), Office for Remote Sensing of Earth Resources

/3/ Turner B.J., "Cluster Analysis of Multispectral Scanner Remote Sensor Data", Remote Sensing of Earth Resources, vol. 1, ed. by Shahrokhi, The Univ. of Tennessee, Tullahoma, Tenn. (1972)

/4/ J.Dejace, J. Megier and W. Mehl. "Computer-Aided Classification for Remote Sensing in Agriculture and Forestry in Northern Italy". Twelfth Int.Symp. on Rem.Sens.of Env., 25-29 April 1977, Ann Arbor, Mich.