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

Third Progress Report

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February 15th – May 15th, 1976

PART I

ACTIVITY PERFORMED ON THE ITALIAN TEST–SITES

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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 QUARTERLY ACTIVITY AND THE RELAVANT RESULTS

Some qualitative results have been obtained out of the experiment of reflectance measurements under greenhouse condition. This experiment being conceived for pinpointing the most significant radiometric features of the two most diffused varieties of rice on test-site no. 1, an effort has been made to correlate phenological stages, production and radiometric measurements. As a conclusion of this particular experiment on rice pots, it has been found that the first order effect of exposure variability to sun irradiation is responsible for different rice productivity classes. To each class different spectro-radiometric reflectance values of ρ_4, ρ_6 and ρ_6/ρ_4 ratio correspond. Variability effects of rice variety and fertilization become of second order because they result to be almost completely masked by the first order effects.

Relationships between variability characters and phenologic stages of open-field rice have been investigated. An attempt has been made to find out a mathematical description of the variability that is a characteristic of the parameters measured on rice cultivation. Reflectance values in the LANDSAT channels and agronomic data have been considered. It was possible to note that the sequence of all the characteristic phenologic stages connected with the rice plants development produces either a change in sign or an inversion or at least a slope change in the statistical Pearson coefficient curves. This demonstrates that variability is probably a very useful tool for discrimination of rice phenologic stages.

Preparation of the data collected on the JRC lysimeters by BGI has been nearly completed. Agronomic and radiometric data have been processed and stored either on punched cards and on minicassettes. Calculations and evaluations are in progress concerning application to rice field condition of a multi-layer canopy model.

Computer-aided classification and inventory of poplars afforested areas using some 1975 LANDSAT scenes have been made. The study showed that acreage estimation of poplar groves from LANDSAT satellite data, in European land situations with reduced planted areas, is able to give useful results, in rather operative conditions, when the input parameters for the automatic classification method are evaluated over reduced training samples of the area studied or even apart from it. A way to improve the accuracy of the results and to limit the dispersion they may have when processing separately several scenes, in a time sequence, over the same geographical area, seems to be a merging of data. Processing of data of several scenes as a unique data set of higher dimensionality has proved to reduce misclassifications as well as partial classifications so that the inventory of wood production results more reliable. The global accuracy achieved for separate NASA scene processings is around 20% of the areas estimated, while processing three scenes together brings the accuracy to better values, up to 5% in the best case, for poplar groves of more than three years old. Dimensionality reduction in the data from 12 to 6 was proven by principal components analysis and has given encouraging results.

Application of classification technique to rice fields has been continued. The accuracy achieved for rice inventory (≃20 % error in rice area evaluation) by processing the single 15/6/75 scene is far from that obtained by level slicing on the 10/7/73 scene (3% error, see 2nd APR). Further studies will be devoted to process other successive available scenes corresponding to different phenological conditions over the same geographical area of test-site no. 1, first separately and then by merging the data together in order to improve the results.

1. INTRODUCTION

The activity herein reported (February 15th - May 15th,. 1976) is the continuation of the preceeding tests which were carried out on the Italian test-sites after the LANDSAT-2 launch by the Joint Research Center - Ispra in collaboration with the Biology Group of the Directorate General for Science and Education and the Italian Institutes and organizations in the frame of the LANDSAT-2 follow-on investigation No. 28790 (AGRESTE PROJECT).

2. LANDSAT-2 IMAGERY ACQUISITION FOR THE ITALIAN TEST-SITES

The CCT tapes ordered from the NASA by the JRC and corresponding to seven scenes for the Italian test-sites (from 2144-09331 to 2234-09322; see 2nd QPR, 3., Table 2, page 3) arrived at Ispra. Some of them have been immediately processed. Following up an offer from TELESPAZIO to the JRC, a quick look has been ... ested for selected Northern Italian imagery in order to fill the gap due to some important scenes missing for irrigated crop (rice) investigation (see 2nd QPR, 3., page 2).

3. ACTIVITY PERFORMED OVER THE CONSIDERED PERIOD

3.1 RESEARCH OBJECTIVES AND TASK DISTRIBUTION

During this 3rd quarterly period of the AGRESTE investigation, the activity has been carried out on the following objectives (see 2nd QPR, 3.1, page 3):

1) Rice investigation:
   - processing and interpretation of greenhouse, lysimeter and field data for correlating reflectance with biomass characteristics
   - completion of some satellite reference ground-truth maps
2) Forest investigation:
   - completion of some satellite reference ground-truth maps

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Table 1 : Task distribution among the AGRESTE co-investigators

	Specific objective	ENR	INLP	ISC	ISP	JRC	BGI
rice investigation	Correlating rice reflectance with fertilization levels, density of sowing, varieties and agro-climatological parameters :						
	under greenhouse conditions			agronomic data preparation and interpretation		spectral and agronomic data processing and interpretation	
	on lysimeters						spectral and conventional data preparation and processing
	on open field	agro-climatological data preparation and interpretation		agronomic data preparation and interpretation		spectral data preparation, processing and interpretation	
	Application of a multilayer canopy model to rice cultivation					spectral and conventional data processing and interpretation	
	Ground-truth preparation	producing partial maps and interpretation (satellite and MSS)				small scale overall mosaic assembling	
forest	Ground-truth preparation		interpreting of photographic maps (satellite and MSS)		interpreting of photographic maps (satellite and MSS)	preparation of reference maps	
satellite data processing	Software preparation					interactive system implementation, development of new utility programs	
	Classification and inventory					application to some 1975 LANDSAT-2 scenes of test-site no. 1 (rice and poplars)	

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3) Computer-aided interpretation of satellite data:
   - application of classification algorithms to some selected areas of rice and poplars on test-site no. 1
   - research of the best approach for classification of natural forest (beeches)

Special emphasis has been put on:

- processing and interpretation of greenhouse and open-field data
- classification and inventory of rice fields and poplar afforestation

The distribution of tasks is summarized in Table 1. The test-zones for the above research are shown in Fig. 1.

3. 2 RICE INVESTIGATION

3. 2. 1 Results of rice reflectance measurements under greenhouse conditions

Radiometric measurements were performed by ISC and JRC on ten pots of rice cultivated under greenhouse conditions (see 1st QPR, 3. 2. 1, page 20). In Table 2 the values of production per pot at harvest are reported.

Table 2 : Production per pot at harvest

Sample (pot) No	Variety	Fertilisation Index	Production (gr/pot)		
			Grain	Straw	Total Biomass
1	Arborio	40	60.20	90.50	150.70
2	Roma	140	54.93	96.15	151.08
3	Arborio	140	64.28	105.14	169.42
4	Roma	40	49.33	98.36	147.69
5	Roma	40	50.27	92.98	150.25
6	Roma	140	34.55	64.01	98.56
7	Arborio	140	41.51	72.92	114.43
8	Arborio	40	34.50	61.76	96.26
9	Roma	140	24.21	63.50	87.71
10	Arborio	40	46.72	70.68	117.40

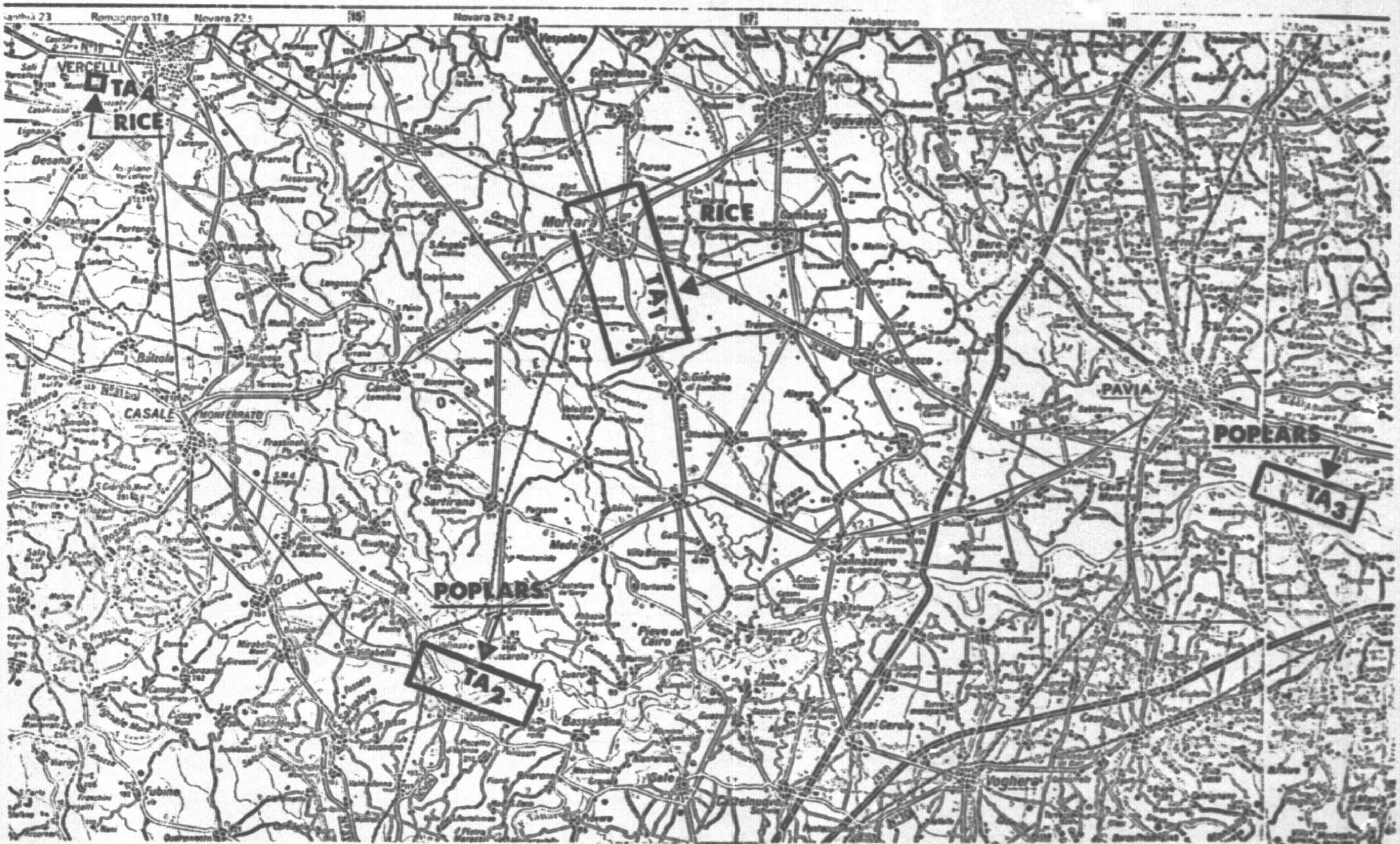

Fig. 1 : Test-zones on test-site no. 1 corresponding to:
a) LANDSAT-2 satellite frames used for digital classification and inventory of rice and poplars (TA_1, TA_2, TA_3)
b) field campaigns for correlating reflectance with biomass characteristics (TA_4)

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Production of caryopsis (grain), straw and total biomass has been measured and is expressed in relative units (gr/pot). From a first analysis of the data it results that, in spite of the variability introduced by some typical parameters as rice variety and fertilization, the greenhouse rice can be regrouped in two different classes. The first class includes pots no. 1 to 5 with relatively high productivity (a. 150 r.u.), while the second class refers to pots no. 6 to 10 with relatively low productivity (a. 100 r.u.). An analysis of the experimental set-up inside the greenhouse (see 1st QPR, Fig. 2-2) has made evident that the separation into two classes comes mainly from two different sun irradiation conditions. In fact, pots no. 1 to 5 belong to an upper row which was in contact with the South-wall of the greenhouse. The effect of this arrangement was just to reduce the sun irradiation impinging on the lower row of the rice pots no. 6 to 10. Therefore, the relatively low production of grain and of the total bio-mass for the latter ones may be explained in terms of a lower incoming energy which has altered and delayed the vegetative cycle of the rice of one row in respect to the other.

From a radiometric point of view this two-class regroupement can be put in evidence by extracting reflectance data for the LANDSAT bands 4 and 6 from Table 2.2 of 1st QPR.

These bands have been chosen in preference to bands 5 and 7 (which are almost equivalent with regard to the radiometric amount of information on vegetation) because the latter ones were affected by an error introduced by the experimental procedure for obtaining integral values on LANDSAT bands out of the differential measured spectra/1/.

In Fig. 2 the mean values of reflectance for band 4 and 6 are reported as a function of time after germination respectively for pots no. 1 to 5 (dashed line) and for pots no. 6 to 10 (continuous line).

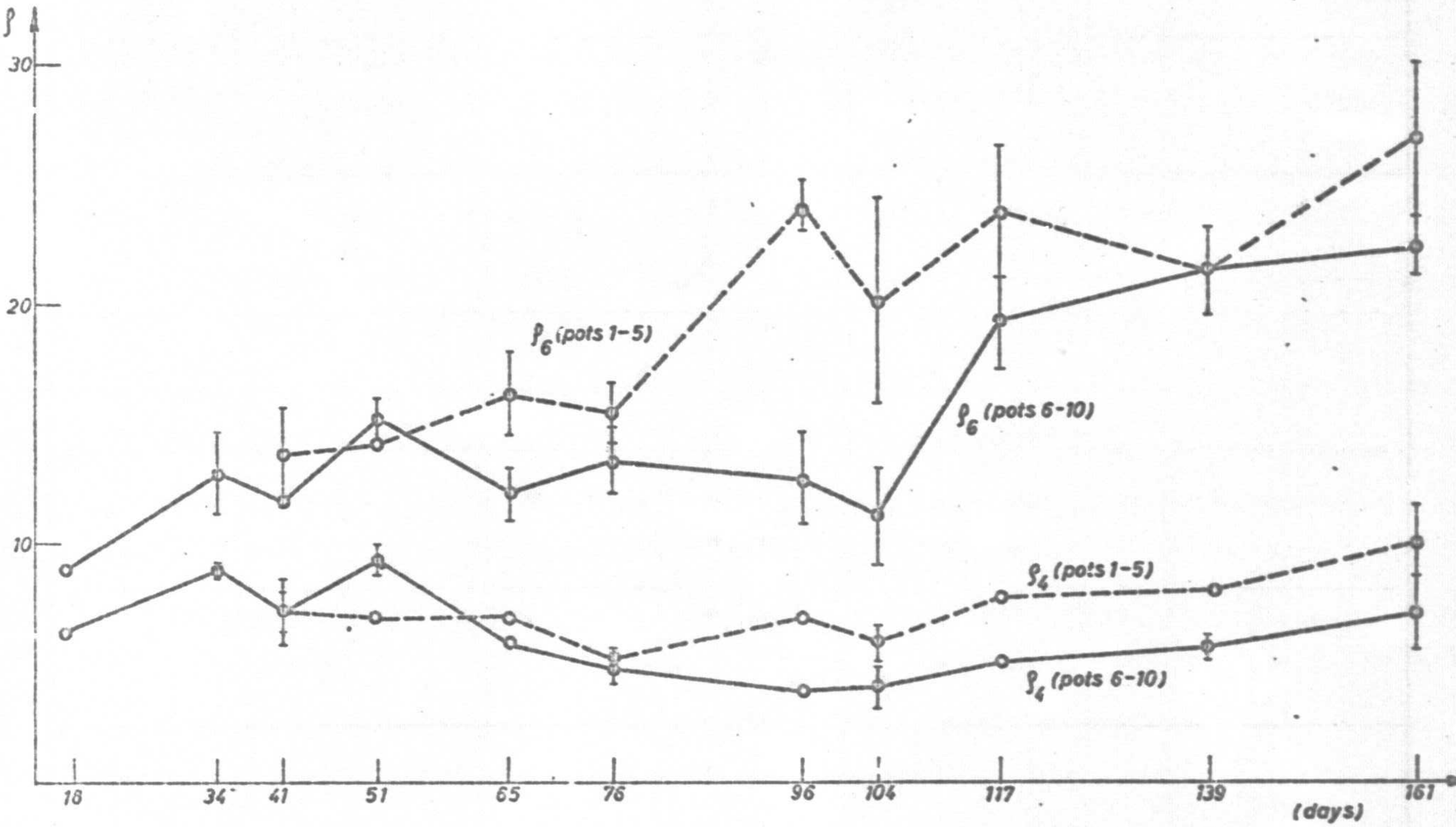

FIG. 2 – Evolution of Reflectances ρ_4 and ρ_6 during the phenological cycle of rice

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It can be observed that in both cases the two lines are significantly divergent after day 76. This result can be interpreted as an effect of the direct sun irradiance which became gradually prevalent with regard to the greenhouse artificial light. In fact, fog which was prevailing in the region of Vercelli before that time, was since then more and more reducing while the days were growing longer.

In Table 3 values of the ratio ρ_6/ρ_4 are reported for different days and pots. An overall indication of the behaviour of S_6/S_4 versus time has been attempted (mean values) separately for the two rice classes. In Fig. 3 the results are reproduced respectively as a dashed line for pots no. 1 to 5 and as a continuous line for pots no. 6 to 10.

In spite of the coarseness of the approach adopted, also these curves show almost the same behaviour until the time of earing/ flowering (day 96). From this day on the ratio ρ_6/ρ_4 for the best exposed rice pots shows a continuous decrease as the rice begins to ripen, until the harvesting.

The less exposed rice pots are radiometrically characterized by a ρ_6/ρ_4 behaviour which, after a prompt decrease at day 104 (probably in coincidence with flowering), resumes an increase.

All this appears to be representative for a vegetative vigour which was delayed with regard to the normal growing cycle. In this respect the radiometrically detected temporal alteration of the growing cycle due to lower amounts of incoming solar energy in the greenhouse, is to be considered responsible for the reduced production of the second rice class.

Conclusions

As a conclusion of this particular experiment on rice pots, it has been found that the first order effect of exposure variability to sun irradiation is responsible for different rice productivity classes.

Table 3 : Ratio ρ_6/ρ_4 for the two classes of rice pots

Sample (pot) No	18.2.74	3.1.75	10.1.75	20.1.75	3.2.75	14.2.75	6.3.75	14.3.75	27.3.75	18.4.75	10.5.75
	18	34	41	51	65	76	96	104	117	139	161
1			1.67	1.79	2.21	2.59	3.50	3.30	2.94	2.67	
2			1.93	1.83	2.34	2.94	3.73	3.99	3.39	2.53	2.62
3			1.85	1.65	2.31	3.13	3.96	3.78	3.23	2.92	2.90
4	1.45		1.96	1.97	2.54	3.36	3.56	3.12	3.28	3.10	2.44
5	1.64	1.77	2.18	2.11	2.28	3.15	3.10	3.24	2.63	2.48	2.14
6	1.37	1.43	1.69	1.79	2.01	3.04	3.00	2.77	3.46	3.67	2.79
7	1.41	1.62	1.70	1.74	2.08	3.13	3.96	2.91	3.89	4.24	2.56
8			1.56	1.62	2.07	3.14	3.71	3.00	4.20	4.13	3.72
9			1.79	1.57	2.09	2.74	3.30	3.05	3.51	3.65	4.33
10	1.39	1.28	1.55	1.46	1.99	2.40	3.16	2.60	3.89	3.38	3.27

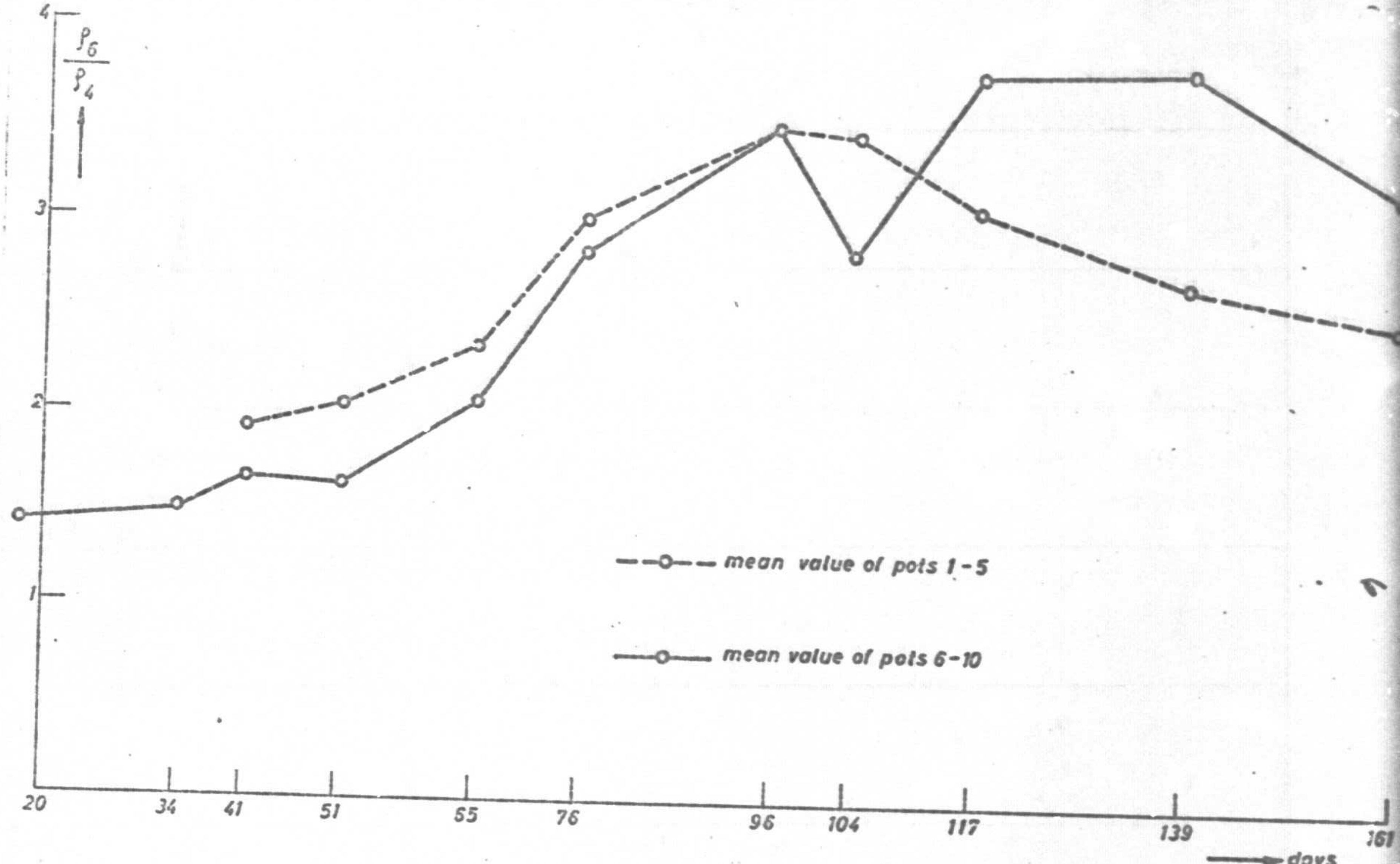

FIG. 3 – Evolution of ratio $\rho 6 / \rho 4$ during the phenological cycle of rice

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To each class different spectro-radiometric reflectance values of ρ_4, ρ_6 and ρ_6/ρ_4 ratio correspond. Variability effects of rice variety and fertilization become of second order because they result to be almost completely masked by the first order effects.

3.2.2 Measurement campaigns on rice fields and lysimeters

3.2.2.1 Processing of data gathered on the JRC's lysimeters

Preparation of the data collected on the JRC lysimeters by BGI is being nearly completed.

Agronomic data. All field data have been processed and sifted following this procedure:

a) putting data on a punched card form
b) tabulating data for different combinations of lysimeter cells and field-drawing dates, which permitted to put in evidence and to eliminate immediately spurious data. Tables summarize agronomic data listed on 1st QPR (3.3.2.1, page 23) for sampling operated on different cells. Basic statistical calculations have also been included (see Table 4a).
c) data have been finally stored on minicassettes for an easier and faster data processing and interpretation.

Leaf surface values (as those listed in Table 4b) have been obtained by means of a program which has also been used in order to calculate successive cummulations of partial leaf index for any rice cell in relation with different growth stages. Storage of more than 40.000 data has been performed.

The results of the chemical analysis for the N_2 content determination (for halms, panicles and lysimeter hearth) will be available by the end of July.

Radiometric data. Reflectance data have been processed separately as far as data gathered respectively by means of OPTRONICS mod. 760 and of EXOTECH mod. 100 is concerned.

Table 4a : Example of tabulation summarizing agronomic data of 1975 lysimeter campaign

ESSAI 3

NO DE LA PARCELLE 12

NBRE DE JOURS APRES LE REPIQUAGE 107

	POIDS SEC (GRS)					IMBIBITION	SURFACE FOLIAIRE (CM2)
	CHAUME FEUILLE MAITRE BRIN (1)	CHAUME FEUILLE TALLE (2)	PANICULE (3)	PLANTE (1)+(2)+(3)	CHAUME FEUILLE +PANICULE	(1)OU(2)	(1)OU(2)
	2.940		3.360		6.300	413	68.62
		3.140	2.300		5.440	369	67.29
		2.695	1.670		4.365	374	74.79
		2.650	3.000		5.650	389	54.71
				21.76			
	4.100		2.190		6.290	361	93.72
		3.280	2.330		5.610	365	80.96
		2.410	1.180		3.590	346	67.29
		4.245	1.670		5.915	350	104.13
				21.41			
	3.890		2.940		6.830	360	92.66
		2.915	2.710		5.625	354	65.09
		3.385	1.770		5.155	350	100.60
		4.625	2.140		6.765	365	134.79
		.545	0.000		.545	436	46.33
				24.92			
	3.000		3.560		6.560	420	72.14
		2.605	2.950		5.555	409	42.36
		2.140	2.820		4.960	407	49.25
		2.890	2.400		5.290	405	64.65
		2.190	1.530		3.720	388	61.12
				26.09			
NBRE DE DONNEES	4	14	17	4	18	18	18
NOYENNE	3.483	2.837	2.384	23.54	5.231	382.20	74.84
ECART-TYPE	.598	.970	.677	2.32	1.491	27.53	23.68
ERREUR STANDARD	.299	.259	.164	1.16	.351	6.49	5.59
DISSYMETRIE	.036	-.310	-.015	.07	-1.650	.30	.80
KURTOSIS	.612	3.419	1.828	.66	5.770	1.67	3.00

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Table 4b : Example of tabulation of cumulative partial leaf index values for 1975 rice lysimeters

ESSAI 3

NBRE DE JOURS APRES LE REPIQUAGE 107

NIVEAU D'INSERTION DES FEUILLES (CM)	INDEX FOLIAIRE PARTIEL CUMULE				
	PARCELLE 11	PARCELLE 12	PARCELLE 13	PARCELLE 14	PARCELLE 15
111			.02		
110	.02				
109					
108					
107			.03		
106					
105					
104			.04		
103	.04				
102	.05				
101	.10	.03	.08	.02	
100		.06		.11	
99	.15			.13	
98		.08	.10	.16	
97	.17	.10	.13	.17	.03
96	.19		.15	.20	
95			.17	.22	.04
94	.21				.06
93		.12	.18	.26	.07
92		.16	.21	.28	
91		.19	.23		.11
90	.23	.21	.25		.13
89	.28	.23	.29	.29	.18
88			.32	.31	
87	.31				
86	.33	.27			
85			.34		
84	.38	.30			
83	.39			.33	
82	.45		.35	.35	.20
81			.39		
80			.42		
79					
78	.49	.32	.45	.36	.24
77	.51				
76	.56				.25
75	.59	.39	.48	.40	
74	.67	.45	.52	.42	
73		.51		.45	.31
72			.59	.70	.36
71	.76			.74	
70			.67		.42
69			.73	.77	.44
68		.54		.83	
67	.81				.45
66		.63	.83		
65				.87	
64			.95	.91	
63	.86	.72	.93	1.02	.49
62		.76			.53
61	.90				.59
60	1.01	.83	1.06		
59	1.09	.87			
58	1.13		1.09		.63
57					
56	1.28			1.06	.68
55		.93		1.11	
54			1.19		.72
53	1.39	1.04	1.24		.79
52	1.44		1.29		
51	1.51				.86
50		1.20	1.36	1.24	.96
49	1.63	1.30	1.52	1.43	1.02
48	1.77	1.35		1.60	1.10
47			1.59	1.64	
46		1.41	1.66		
45			1.77	1.71	1.14
44	1.84		1.89		
43				1.89	
42				1.96	1.19
41			1.95	2.08	1.24
40	2.01	1.58	2.04		1.37
39		1.63			1.41
38	2.08	1.74	2.11		
37	2.30				1.47
36	2.38			2.14	1.58
35	2.44			2,20	
34		1.99	2.16	2.32	1.68
33				2.49	1.73
32			2.22		1.77
31			2.28	2.60	
30					1.87
29					
28		2.08			1.91
27					
26		2.16			
25					
24					
23					1.95
22					1.99
21					
20					2.01

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OPTRONICS mod. 760 data. Spectral reflectance curves have been digitized on the wavelength range (0.4 - 1.06) µm with a resolution of 10 nm. Processing of the punched tape data has been performed making use of special software. Integration took place on the four LANDSAT spectral bands (see Table 5a). The phenologic extent of the nine measurements period being sufficiently large (early July to end September), it seems that coherent and satisfactory results can be obtained.

EXOTECH mod. 100. Fifteen measurements have been made in the period early August to middle October. All the data have been processed following the same procedure as the one adopted for agronomic data (see Table 5b).

The present effort is concentrated in the following directions:

- differentiating rice lysimeters on an agronomic point of view (following the principal influencing parameters: fertilization and transplanting)
- establishing relationships between rice phenological cyclè characteristics and its spectral response
- obtaining some information on the possibility of correlating rice reflectance properties with productivity

3.2.2.2 Connections between variability characters and phenologic stages of open-field rice

The results gained out of the campaign on rice fields in Vercelli in 1974 showed that any time dependent model of the plant growth and development should take into account the wide variability that is a characteristic of the parameters measured on open field cultivation. According to these considerations it seemed convenient to devote the 1975 campaign to the attempt of finding out a mathematical description of such variability and some possible connections with rice phenologic stages. For this purpose a rice field of the ISC at Ver-

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8-a

Table 5a : Example of tabulation of digitazed OPTRONICS mod. 760 curves (continuous wavelength range 0.4 ÷ 1.06 μm, resol. 10 μm). Integration has been made on the 4 LANDSAT channels

REFLECTANCE MEAS.LYS.1975 SAMPLE.NC 4606 WITH CALCOMP

SLITWIDTH= 2.50

ZERO-CURRENT= 0.CCCE+CO AMPERE

NO OF LAMBDA-CARDS READ= 67

LAMBDA (NM)	FIL-TER	SAMPLE-CUR-RENT(AMPERE)	PANNEL-CUR-RENT(AMPERE)	SAMPLE-RADIA-NCE(W/CM**2*NM)	PANNEL-RADIANCE (W/CM**2*NM)	RELATIVE-SAM-PLE-REFLECTANCE	SAMPLE-REFLECTANCE
400.00	2	[illegible]	1.1742E+02	1.11429E+02	1.50096E+03	0.0369	0.0113
410.00–860.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
870.00	3	2.5140E+02	1.5239E+02	6.34476E+03	4.19030E+03	0.7573	0.3711
880.00	3	2.6694E+02	1.8542E+02	6.23563E+03	4.02945E+03	0.7738	0.3753
890.00	3	[illegible]	1.8790E+02	6.01322E+03	4.03752E+03	0.7445	0.3626
900.00	3	2.2724E+02	1.7661E+02	4.92751E+03	3.53941E+03	0.6820	0.3335
910.00	3	2.2209E+02	1.6766E+02	4.63780E+03	3.53513E+03	0.6623	0.3232
920.00	3	[illegible]	[illegible]	4.96339E+03	3.49915E+03	0.6597	[illegible]
930.00	3	[illegible]	[illegible]	4.11443E+03	3.31207E+03	0.6212	0.3019
940.00	3	1.1325E+02	1.1345E+02	2.35350E+03	2.35475E+03	0.4991	0.2421
950.00	3	1.3207E+02	1.1591E+02	2.74525E+03	2.48491E+03	0.5547	0.2695
960.00	3	[illegible]	1.3459E+02	3.03417E+03	2.80338E+03	0.5412	0.2614
970.00	3	[illegible]	1.5066E+02	4.09207E+03	3.36085E+03	0.6088	0.2934
980.00	3	2.0762E+02	1.6722E+02	4.47139E+03	3.60131E+03	0.6209	0.2956
990.00	3	2.3179E+02	1.7232E+02	5.20368E+03	3.67032E+03	0.6723	0.3234
1000.00	3	2.2532E+02	1.7237E+02	5.27642E+03	4.02753E+03	0.6550	0.3144
1010.00	3	[illegible]	1.6206E+02	5.33707E+03	4.12655E+03	0.6467	0.3098
1020.00	3	[illegible]	1.5606E+02	5.39660E+03	4.34545E+03	0.6396	0.3038
1030.00	3	1.7246E+02	1.5228E+02	5.62644E+03	4.57690E+03	0.5661	0.2701
1040.00	3	1.5351E+02	[illegible]	5.90412E+03	5.23970E+03	0.5535	[illegible]
1050.00	3	1.3430E+02	1.1967E+02	6.32186E+03	5.60494E+03	0.5640	0.2679
1060.00	3	1.1507E+02	5.8653E+01	6.98832E+03	5.59130E+03	0.5832	0.2764

NO OF POINTS= 67

ERTS CHAN.	NO	MEAN SAMPLE RADIANCE (W/CM**2*NM)	MEAN PANNEL RADIANCE (W/CM**2*NM)	MEAN IRRA-DIANCE (W/CM**2*NM)	CHANNEL REFLECTANCE ×2
	1	9.3378E+02	5.5C98E+03	1.0711E+04	0.0872
	2	7.1646E+02	5.C758E+03	9.9822E+03	0.0718
	3	4.9540E+03	4.4953E+C3	9.0288E+03	0.5487
	4	5.4CCEE+03	3.5819E+C3	7.2568E+03	0.7442

ERTS CHAN.	NO	INT. SAMPLE RADIANCE (W/CM**2*NM)	INT. PANNEL RADIANCE (W/CM**2*NM)	INT. IRRA-DIANCE (W/CM**2*NM)	CHANNEL PASS-BAND (NM)
	1	8.4956E+04	5.0125E+C5	9.7447E+05	90.98
	2	8.4129E+04	5.96C0E+05	1.1721E+06	117.42
	3	6.0587E+05	5.45C4E+C5	1.1042E+06	122.30
	4	9.2681E+05	6.1467E+05	1.2451E+06	171.60

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8-B

Table 5b : Example of tabulation of EXOTECH mod. 100 data for the 1975 lysimeter campaign

ESSAI 3

NOMBRE DE JOURS APRES LE REPIQUAGE 102

HEURE	NO PARCELLE	REFLECTANCE (%)-RADIOMETRE EXOTECH MOD.100				RAPPORT DE CANAUX	
		CANAL 4	CANAL 5	CANAL 6	CANAL 7	C7/C5	C6/C4
12.13	11	4.05	4.43	26.07	38.59	8.70	6.44
12.12	12	3.50	3.84	24.09	36.29	9.45	6.88
12.15	13	3.63	3.97	23.13	33.37	8.41	6.37
12.09	14	4.19	4.42	25.41	36.41	8.23	6.07
12.10	15	3.89	4.44	25.23	36.02	8.12	6.49
MOYENNE		3.85	4.22	24.79	36.14	8.58	6.45
ECART-TYPE		.29	.29	1.17	1.86	.53	.29
ERREUR STANDARD		.13	.13	.52	.83	.24	.13

celli was subdivided into thirty ideal cells on which every week measurements were performed (from July to October) according to the following procedure:

a) measurement of reflectance in the four LANDSAT channels (by means of an EXOTECH mod. 100 radiometer) on two points randomly selected on each cell
b) evaluation of the weight of wet and dried biomass (halms and panicles) of 10 rice plants randomly withdrawn in each cell.

Our of the data collected (60 measurements concerning point a), 30 field-drawings concerning point b)), the following parameters have been calculated:

- mean value (μ)
- standard deviation (σ)
- Pearron coefficient ($\beta = \frac{\frac{1}{N}\Sigma(x_i-\mu)^3}{\sigma^3}$) where x_i are measured reflectance values.

The values of μ, σ, σ/μ, β have been plotted against time, both for radiometric and ground collected data. The time zero corresponds to the first measurement day. At this moment it is not yet possible to draw satisfactory conclusions about the ground collected data because the interpretation of some apparent anomalies requires further investigation on the local conditions which may have influenced some sampling operation.

On the other hand very interesting considerations can be made on the reflectance diagrams shown in Figs. 4 and 5 for the LANDSAT channels 5 and 7, particularly as far as the behaviour of the Pearson coefficient is concerned. In fact, looking at the diagrams of the Pearson coefficient related to the two radiometric channels 5 and 7 (β_5 and β_7), one can observe some peculiar coincidences in correspondence of well defined days (see Table 6).

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9a

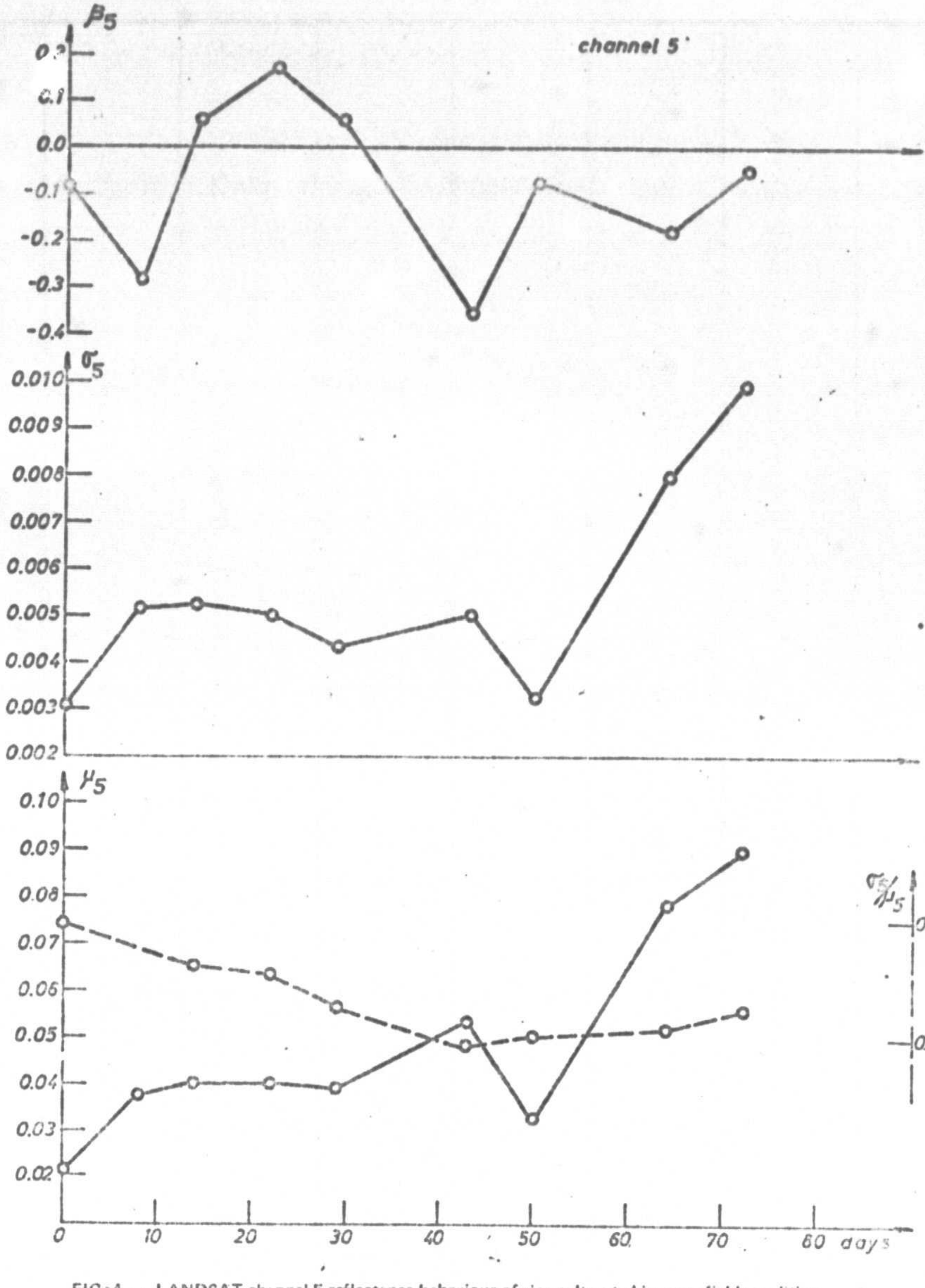

FIG. 4 — LANDSAT channel 5 reflectance behaviour of rice culturated in open field condition (mean value, standard deviation and Pearson coefficient)

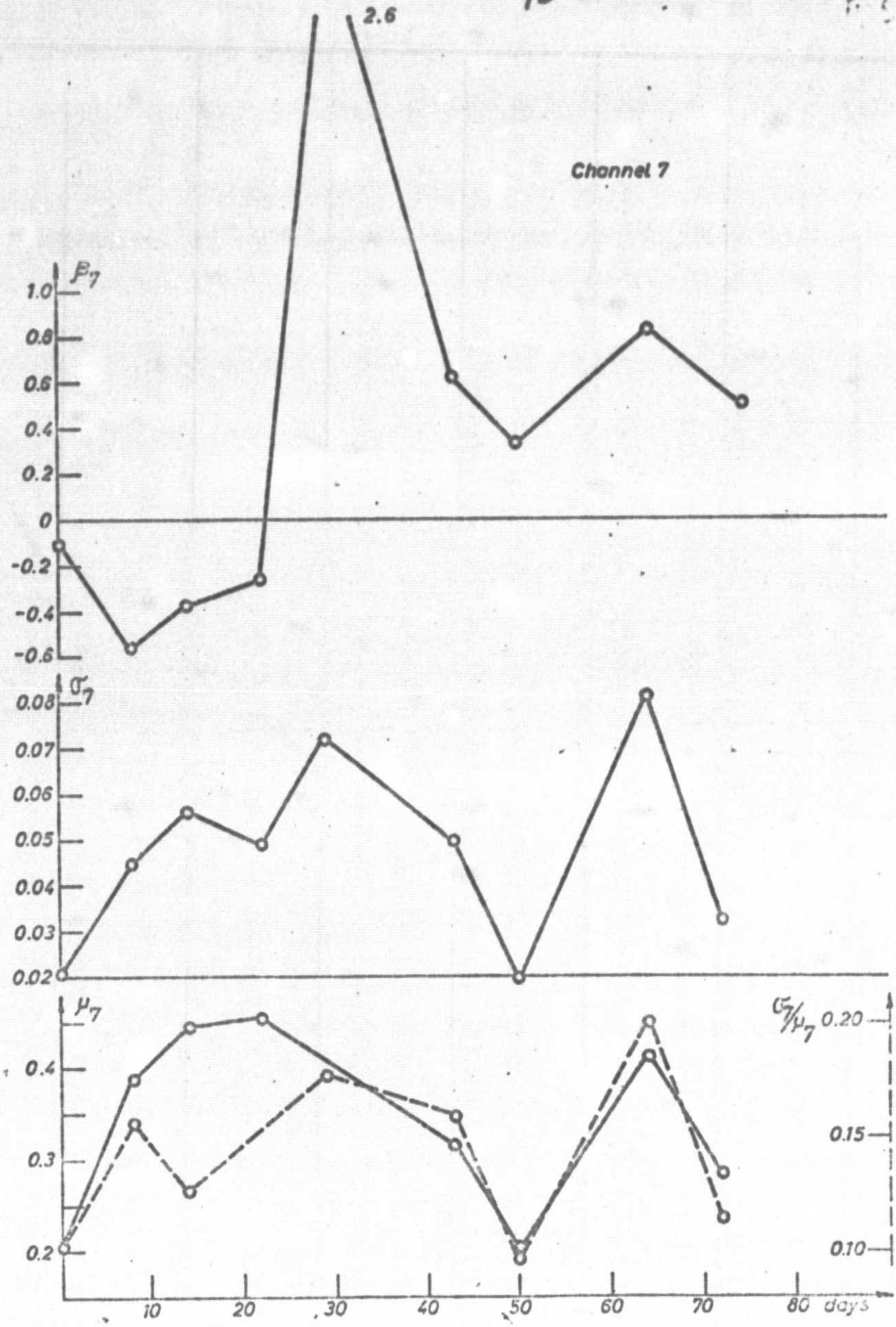

FIG. 5 – LANDSAT channel 7 reflectance behaviour of the rice cultured in open field condition (mean value, standard deviation and Pearron coefficient)

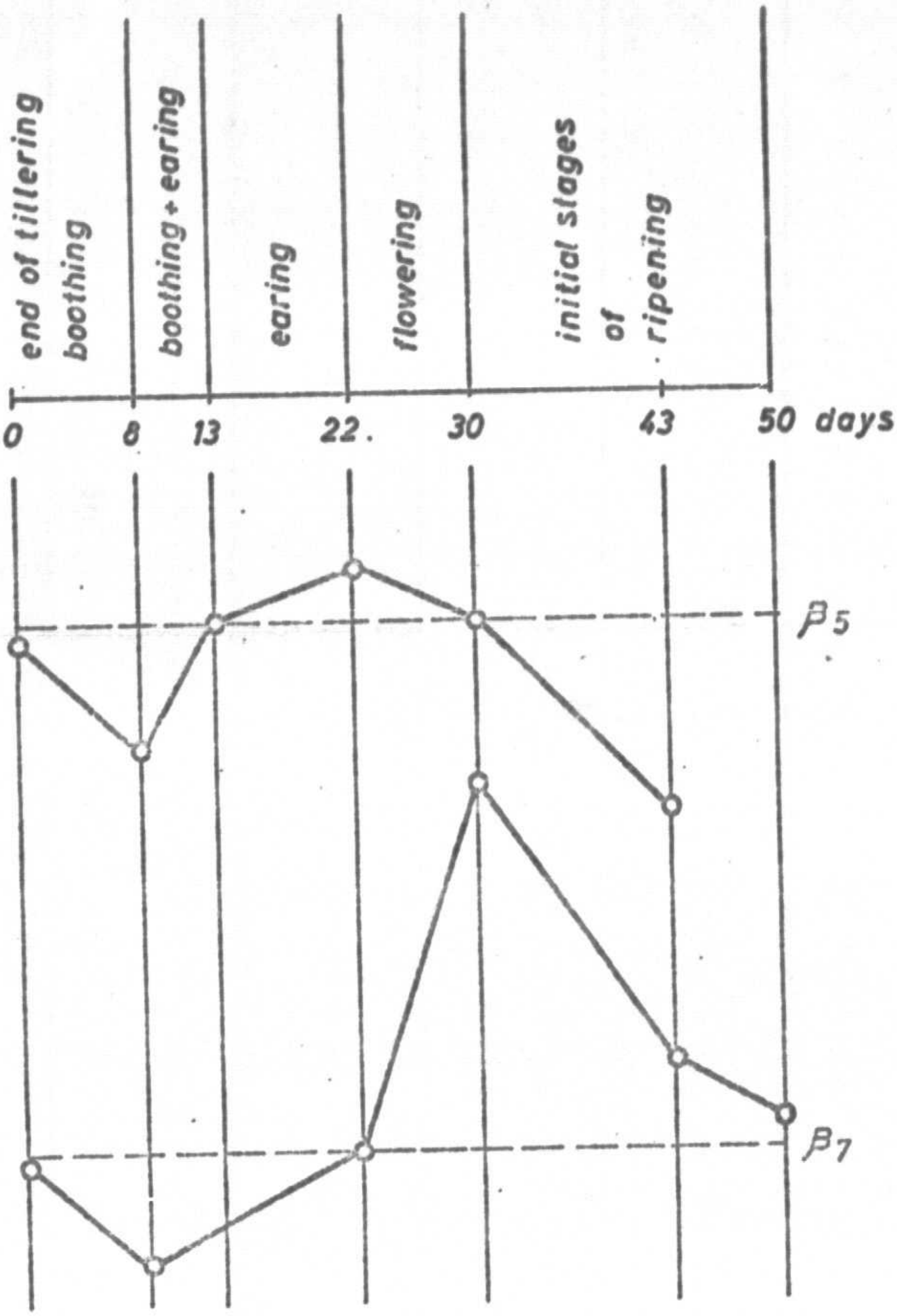

FIG. 6 – Pearson coefficient's evolution for channels 5 and 7
versus different phenologic rice stages

Table 6 : Pearson coefficient values for some 1975 dates of rice growth

Time	β_5	β_7
a.0	0	0
8	min	min
13	0	–
22/23	max	0
29/31	0	max
43/45	min	min

The results have been sinthesized in the diagram of Fig. 6, where the phenologic stages are associated with the time scale. We note that the sequence of all the characteristic phenologic stages connected with the rice plants development produces either a change in sign or an inversion or at least a slope change in the Pearson coefficient curves.

At this stage of the research it is not deemed wise to try to get down into more detailed analysis on the basis of the few measurements performed at Vercelli in only a few large spectral bands. Nevertheless it appears that the variability analysis is probably a very useful tool for the identification of rice phenologic stages and hence a good start towards the determination of a time dependent model of the plant growth and development.

3.2.3 Application of a multilayer canopy model to rice field condition

JRC calculations and evaluations are in progress. An AGRESTE report is in preparation.

3.2.4 Ground-truth preparation

The ground-truth rice acreage for a test area on test-site no. 1 has been calculated out of a reconstituted map as indicated in 3.4.1.1, page 11 by means of the instrumentation of ISP.

3.3 FOREST INVESTIGATION

3.3.1 Ground-truth preparation

The ground-truth acreage calculations and map preparation have been performed for two test-areas of test-site no. 1 as indicated in 3.4.1.2, page 14.

3.4 SATELLITE DATA PROCESSING AND INTERPRETATION

3.4.1 Computer aided interpretation of some 1975 LANDSAT scenes

3.4.1.1 Classification and inventory of rice cultivated areas

As mentioned in the 2nd QPR (2., page 2) some important 1975 scenes are missing for irrigated crop (rice) which would correspond to a peculiar farming situation on test-site no. 2: field flooding. The period concerned ranges from mid April to beginning of June, when water surface of flooded rice fields is free from vegetation. Owing to this absence a first important discrimination of rice cultivated areas out of the context, using a simple level slicing technique (see 1st QPR, 2.2.3.3.2, pages 17-18) was not possible.

The satellite scene used for the data processing application, hereunder reported, is the earliest available (in 1975) for rice investigation. It refers to the June 15th situation when canopy spectral differences of rice growing in various places introduce a high variability of reflectance data gathered by the satellite. This caused difficulties for discrimination of rice out of other surrounding vegetal species. The work concerned a rectangular satellite frame of 9 x 3.25 km^2 on test-site no. 1 including the town of Mortara (see Fig. 1). For this zone the ground-truth rice acreage was calculated by:

a) tranrferring the rice fields location from the cadastral maps on an aerial photo coverage made in August 1975
b) computing the rice areas out of a digitized contour mapping of rice fields. (This has been performed by A. Lapietra, ISP.)

The overall error of this procedure is less than 2% of the evaluated area.

The LANDSAT-2 digital data were first investigated by combining a clustering method with an uniformity mapping procedure. The euclidian distance has been used as a similarity measure between data vectors. This combination was chosen in order to put in evidence clusters of data points which make sense from the point of view of their geographical location and to map them as a function of their uniformity degree.

As a result of such preliminary analysis, four "classes" of rice (R_1 to R_4) were identified having each a unimodal distribution function for each channel and a rather narrow variance value. The relevant mean values (μ) and variance values (σ^2) are reported in Table 7.

Table 7 : Mean and variance values for the first set of rice classes

Rice classes		LANDSAT-2 MSS channels 4	5	6	7
R_1	μ	24.4	21.6	50.1	21.5
	σ^2	0.247	0.247	1.46	1.19
R_2	μ	24.5	21.5	45.8	18.7
	σ^2	0.725	0.389	1.71	1.16
R_3	μ	26.6	27.5	46.2	19.6
	σ^2	0.993	1.64	1.40	1.24
R_4	μ	26.3	23.9	42.18	15.8
	σ^2	1.83	2.00	4.1	1.20

Some non-rice classes were also identified out of the rice investigated area by means of the above procedure.

Starting from the four rice classes and from three non-rice classes, a first classification and mapping of the zone under study was performed using a maximum likelihood classifier. As expected, this step gave some over-sized results in percent of the overall rice cultivated area (50%) compared with the reference ground-truth value (35%). But it was taken as a basis in order to define (in connection with the ground-truth) five quite reliable sampling areas which correspond to five rice classes ($R_{1/2}$ to $R_{5/2}$). The corresponding training sets were cleaned from marginal or anomalous points in order to enable that they exhibit unimodal distributions. No care was purposely devoted to the fact that the new classes are largely overlapping (owing to the great variance values, as shown in Table 8), in order to keep the entire variance amounts of the rice data (provided they are splitted in unimodal distributions well fitted for the maximum likelihood classifier).

Table 8 : Mean and variance values for the second set of rice classes

			LANDSAT-2 MSS channels			
			4	5	6	7
Rice classes	$R_{1/2}$	μ	24.3	21.7	46.9	19.1
		σ^2	1.11	0.93[illegible]	9.18	3.37
	$R_{2/2}$	μ	28.8	20.8	43.2	17.2
		σ^2	1.16	0.821	35.7	14.0
	$R_{3/2}$	μ	25.3	22.8	45.2	18.3
		σ^2	1.37	2.11	11.5	4.84
	$R_{4/2}$	μ	27.8	26.1	48.0	19.1
		σ^2	1.84	3.07	12.5	3.34
	$R_{5/2}$	μ	25.1	23.4	45.3	17.9
		σ^2	1.86	2.89	21.5	9.04

13a

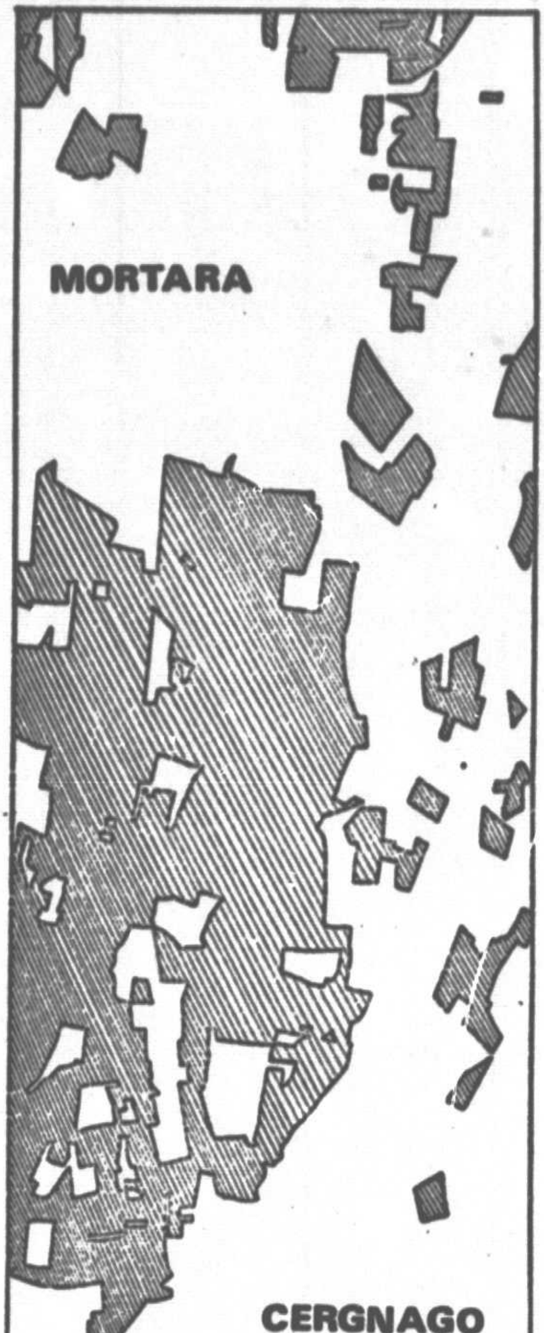

FIG. 7a – Ground truth for the rice test-area of Mortara (TA_1, scale 1/48.000)

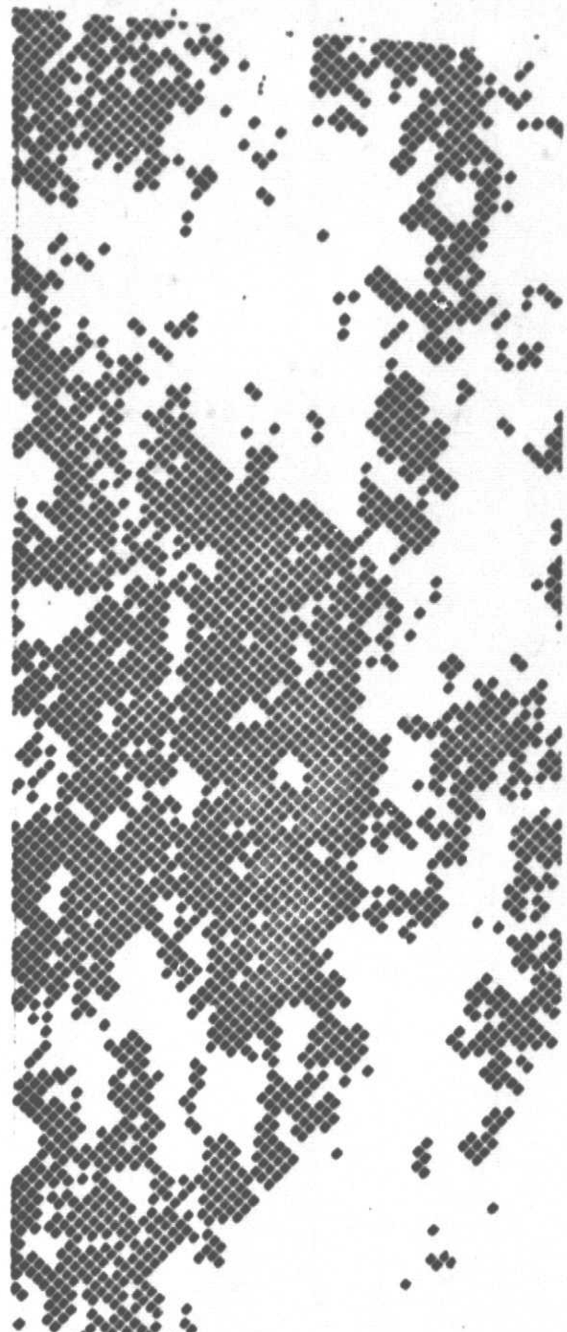

FIG. 7b – Classification display for the same rice area.

The classification and mapping results using this second set of classes together with three non-rice classes, showed that a trade-off was needed between non-recognition of rice zones and misclassification as rice of non-rice zones by setting a proper "membership threshold" on rice classes. The classification results are mapped in Fig. 7b and can be compared to the ground-truth displayed in Fig. 7a. They were obtained by setting on each rice class a rejection threshold of 3% of the maximum probability of the corresponding class distribution.

The global rice percentage area was found to be 43%, while the ground-truth value was 35.5%.

Conclusions

It must be noted that the accuracy achieved for rice inventory (21% error in rice area evaluation) by processing the single 15/6/75 scene is far from the one obtained by level slicing on the 10/7/73 scene (3% error, see 2nd QPR). Further studies will be devoted to process other successive available scenes corresponding to different phenological conditions over the same geographical area of test-site no. 1, first separately and then by merging the data together for improving the results.

3.4.1.2 Classification and inventory of poplar afforested areas.

In this section synthetic results gained from the analysis of three 1975 LANDSAT-2 scenes are reported. Two afforested zones along the Po river have been investigated. The first, TA_2, has an area of 16 km^2. The second, TA_3, has an area of 17 km^2 and is situated 50 km downstream to the first one, at the confluence of the Po and its tributary the Ticino. These zones are both typical for poplar cultivation in Italy, which is concentrated for about 25% along the Po river and which assumes a great importance in the production of wood pulp for the paper industry. (See Fig. 1)

Table 9 : Subdivision of poplars in age and development classes

		Plant age (years)										Ground coverage	Symbols for classes
Dimension classes	1	1	2									< 25 %	
	2		2	3									
	3				4	5	6					25 % – 75 %	
	4						6	7	8	9	10	> 75 %	

The relevant ground-truth (Figs. 8 and 9) were obtained by means of conventional photo interpretation of an aerial I. R. photographic coverage (scale 1/10000) which was performed by ISP in August 1975 (see 1st QPR, 3.3.1.1, page 31). Areal percentages of poplar plantations have been calculated in the same way as for the ground reference rice fields (3rd QPR, 3.4.1.1). Poplars were subdivided by ISP into three/four classes, corresponding to different age and development values, as indicated in Table 9. Each class corresponds to a different range of relative grown dimension, i.e. of percentage of ground coverage by poplar foliage seen by the satellite. The dates of the three LANDSAT-2 scenes (1975) considered for this investigation are June 15th, July 3rd and September 13th.

A supervised classification procedure was applied. The general idea was to perform training of classification algorithm in a few limited zones of area TA_2 for the three NASA scenes and thus to check, from an operative point of view, the reliability of the classification results for the whole area TA_2 and, moreover, for area TA_3 where no training was done/2, 3/. Training of maximum likelihood algorithm was performed on three poplar groves of TA_2 belonging to classes 3 and 4. A mapping view of the zone TA_2 is reported in Fig. 8. The training sample area is located to the South of the Po river, where presence of poplars of classes 3 and 4 is dominant.

Zones TA_2 and TA_3 were then classified separately for each scene starting from training of the above sample of zone TA_1. The results demonstrat a good capacity of the method of recognizing poplar groves of classes 3 and 4. In spite of a general tendency to misclassify some areas (non-poplar objects classified as poplars), it was possible to recognize a couple of poplar groves of class 2 on the scenes of respectively June 15th and September 13th.

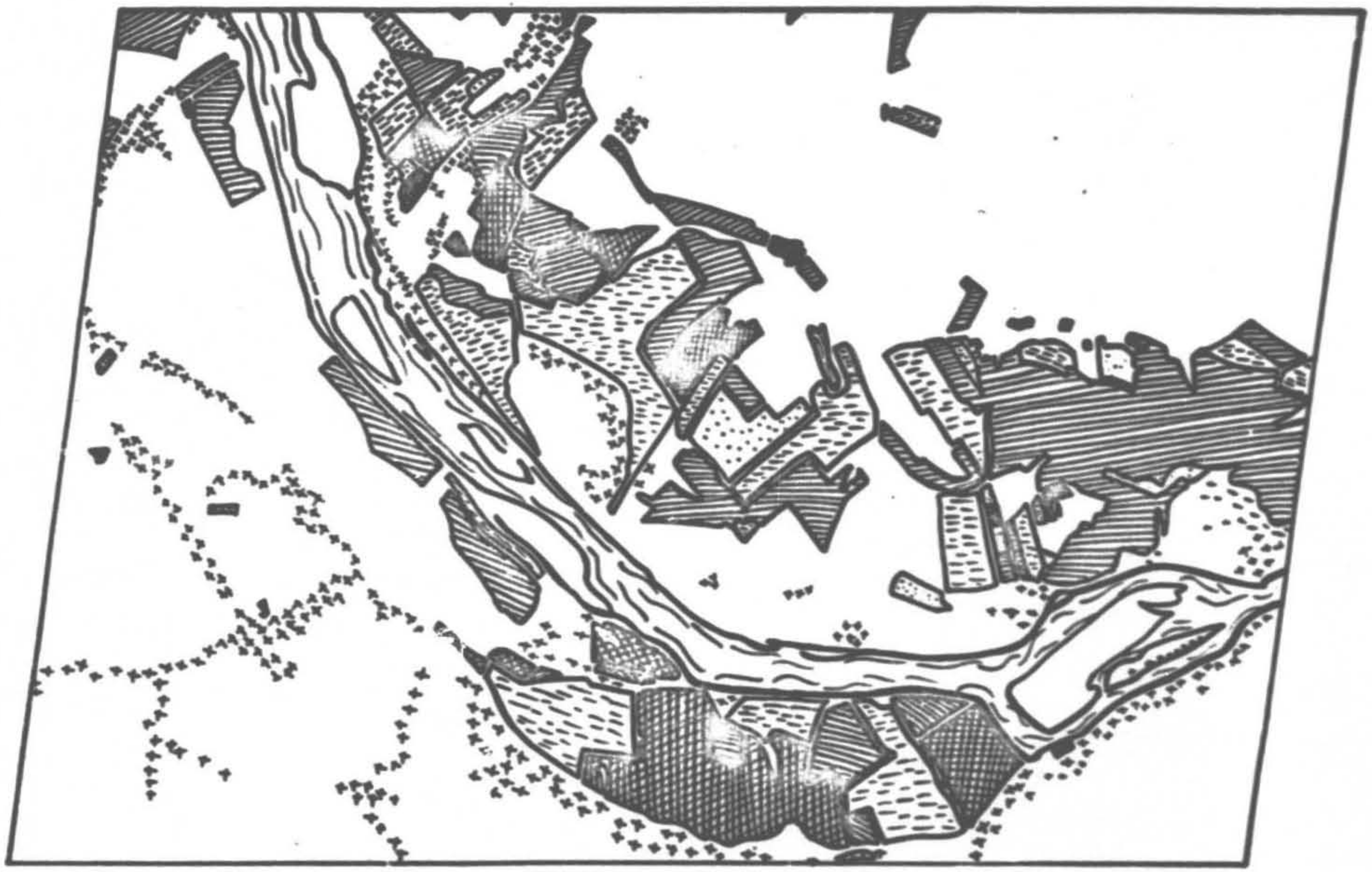

Fig. 8 : Ground-truth for zone TA_2 (scale ≅ 1/28000):

poplar class 1

poplar class 2

poplar class 3

poplar class 4

natural wooded areas containing mainly poplars, willows and false acacia trees ++++

Training was performed on three poplar samples of class 3 and 4, located to the South of the Po river

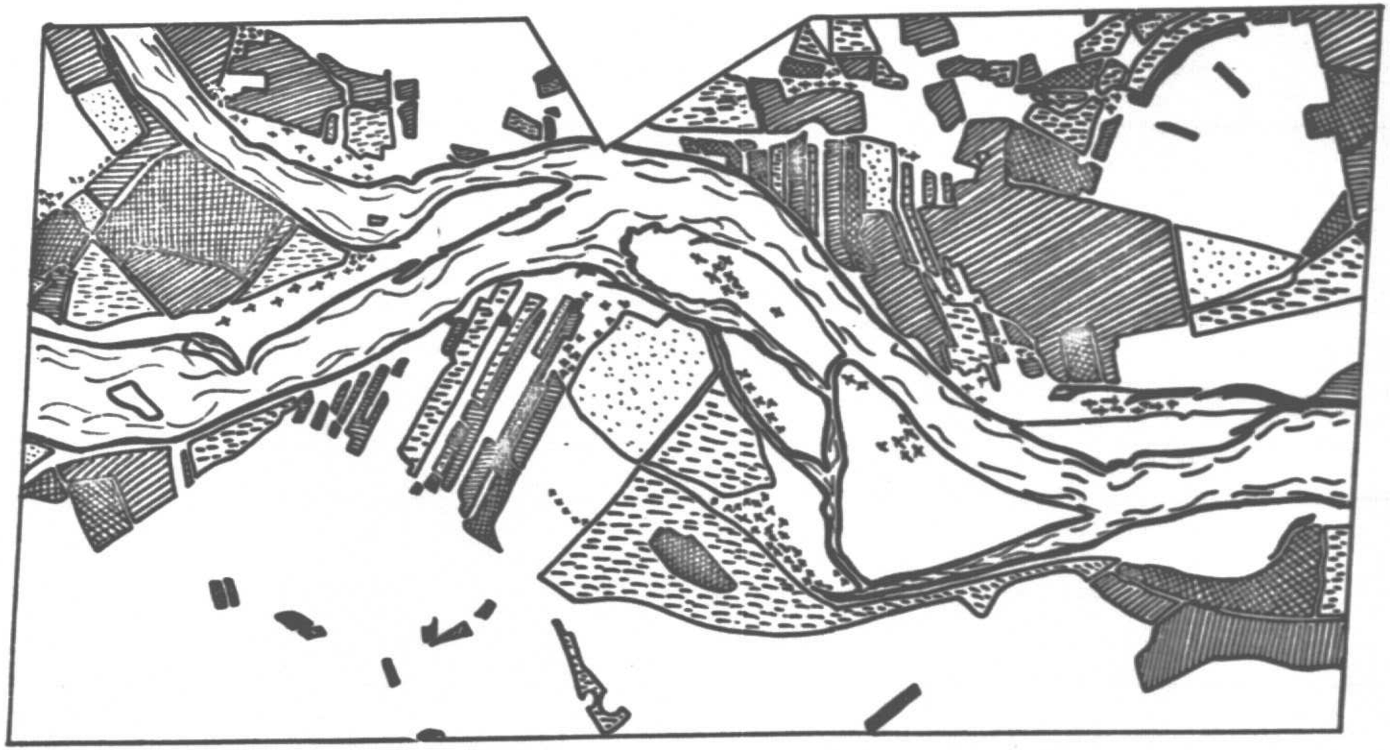

Fig. 9 : Ground-truth for zone $\widetilde{TA}_3$ (scale ≅ 1/30.000) : same class symbols as for zone $\widetilde{TA}_2$ (see Fig. 8)

No training was retained on poplar groves of classes 1 and 2. In fact, it appeared that the corresponding ground coverage is not sufficient in this case and the variability of ground condions (mainly due to different types of low vegetation) causes a great dispersion of the classification results.

A remarkable improvement was obtained by applying a merging technique to the data of the three scenes. They were processed together as two separate twelve-channel data sets for zones TA_2 and TA_3. For this purpose the overlay of the data of the three scenes was performed for each zone with a maximum error of half a pixel in the two directions (lines and columns).

Results are displayed in Figs. 10 and 11. It appears that almost all the poplar groves of classes 3 and 4 are recognized as only groves of these two classes. In this case misclassification is reduced to a minimum as appears in the quantitative results reported in Table 10.

Table 10 : % of poplar afforested areas for classes 3 and 4. Results of classification by max. likelihood are compared with ground-truth

	TA_2 %	TA_3 %
Ground-truth	15.2	17.5
Digital classification	14.5	14.5
Error	– 5	– 17

Conclusions

As a consequence of the application of three scenes merging technique:

a) cancellation of most of the misclassification effects in the individual scene processings can be obtained, and

b) a clear recognition (and inventory) of the poplar groves of classes 3 and 4 becomes possible.

This result is important considering that those two older age and development classes are quite representative for the whole poplar life.

16a

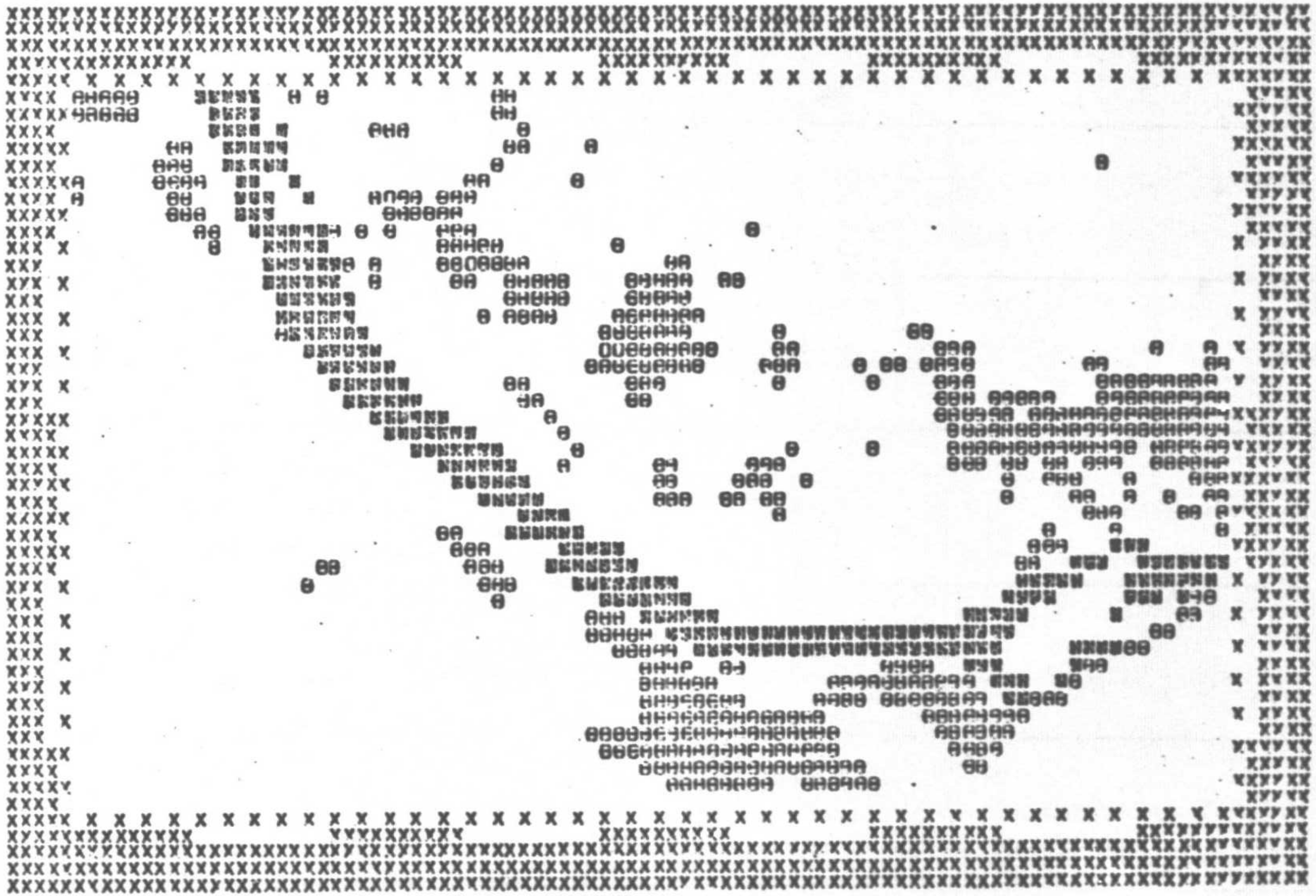

FIG. 10 — Classification results for zones TA_2 of Fig. 8 using the max. likelihood classification algorithm and by merging three different LANDSAT-2 scenes of the same area (12 channels) ■ water Θ poplars

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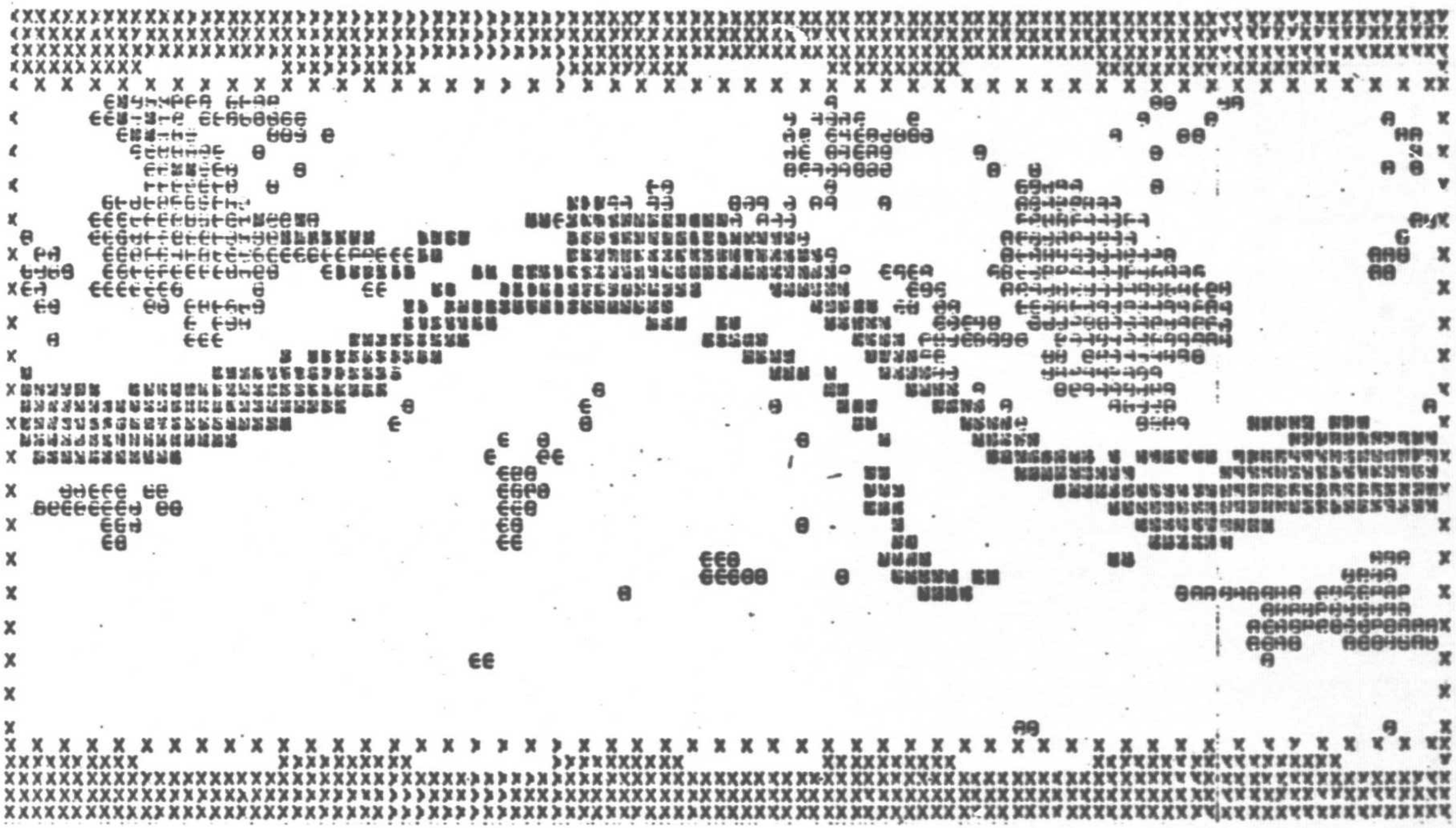

FIG. 11 — Classification results for zone TA_3 of Fig. 9 using the max. likelihood algorithm trained in zone TA_2 and by merging three LANDSAT-2 scenes (12 channels) ■ water Θ poplars

In fact, these two older classes contain all the wood available each year for industrial needs, i.e. 90% of the overall timber volume.

As the data from 12 channels are likely to be redundant, a feature selection to reduce the number of the channels will be investigated later on.

3.4.2.3 Classification of natural beech forest

Work has been started using supervised and non-supervised technique on test-site no. 3, over the natural beech areas to the West of Cuneo (Vallone dell'Arma) using as ground-truth an aerial I. R. photo coverage performed in 1974 and interpreted in 1975 by the INPL's specialists.

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/2/ A. Lapietra (ISP-Casale), J. Megier (CCR-Ispra), "Acreage estimation of poplar planted areas from LANDSAT satellite data in Northern Italy", Int. Union of Forestry Research Org. XVI IUFRO World Congr. Oslo, Norway, June 20-July 2, 1976

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