CONSIGLIO NAZIONALE DELLE RICERCHE
ISTITUTO PER LA GEOFISICA DELLA LITOSFERA

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Posta: GEOLAB, Via Mario Bianco, 9
Telefono (02) 2840227 - 2899905

E7.7-10178
CR-153276

C.M.MARINO
P.I.
Cattedra di Fisica Terrestre
Università degli Studi-Milano

E.ZILIOLI
Istituto per la Geofisica della
Litosfera-Milano
Consiglio Nazionale delle Ricerche

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F I N A L R E P O R T

Investigation n.28450

Geomorphic and Landform Survey of Northern Appennine Range (N.A.R.)

28450

ABSTRACT

A first approach to the Landslide hazard detection is developed through the analysis of some satellite imagery (Landsat 2) showing many Landslide areas that occur on marine silts and clays of Northern Appennine Range in Italy.
A Landslide risk score is given for large areas by the narrowing and the extension, during the time, of well defined areas whose behaviour and reflectivity variation is due to the phisical parameters of the upper surface changes.
The results are that this methodology allowed us to distinguish the pattern evolution of the clayey outflows.

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Above we can see the summer image where the smoothing of the vegetation eliminates many categories which appear, on the contrary, in winter time (below)
Scale 1:250.000.

INTRODUCTION AND SCOPE OF THE INVESTIGATION

The control of landslide prone areas is one of the major problems in our country especially during the last 30 years.

Several techniques are used actually in order to have up to date informations on this kind of phenomena all over the Appennine Range.

Unfortunately both the utilization of time consuming techniques (field geology mainly) and local administrative conflicts of competence are not able to supply regional and state administrations with data on a yearly (or seasonal) revised basis.

Considering that at least after each rainy period of few days new configurations of these phenomena take place in several areas it is easily understood that the use (or the aid) of the greatest possibility offered by Landsat in observing and quantifying of large extensions in a short time becomes mandatory.

For these reasons a research program titled:" Geomorphic and Landform Survey of Northern Appennines Range..." was submitted to NASA in order to test in a appli cative approach the use of space coming information in a defined but largely representative test area.

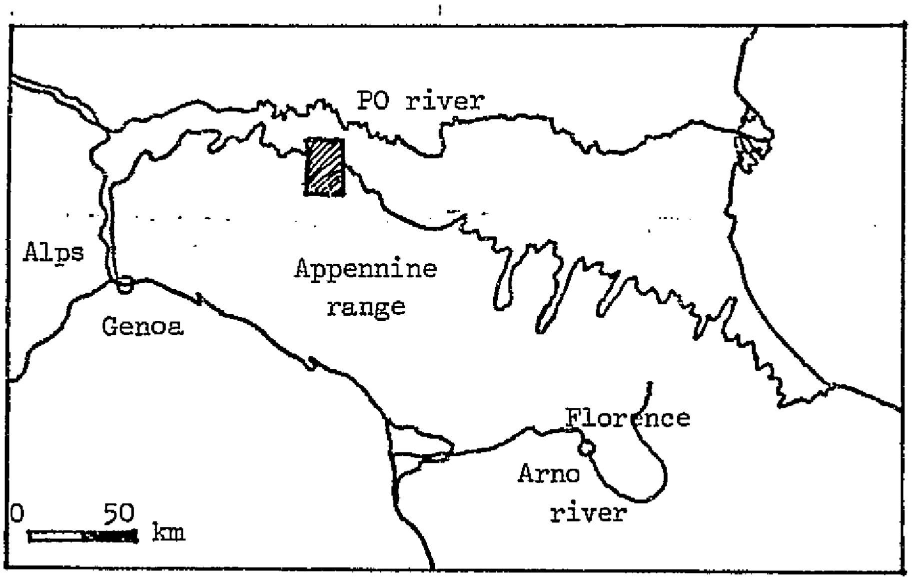


Fig.1 - Location of the investigated area

Fig. Ia - Location of the investigated area (scale : I:200.000)

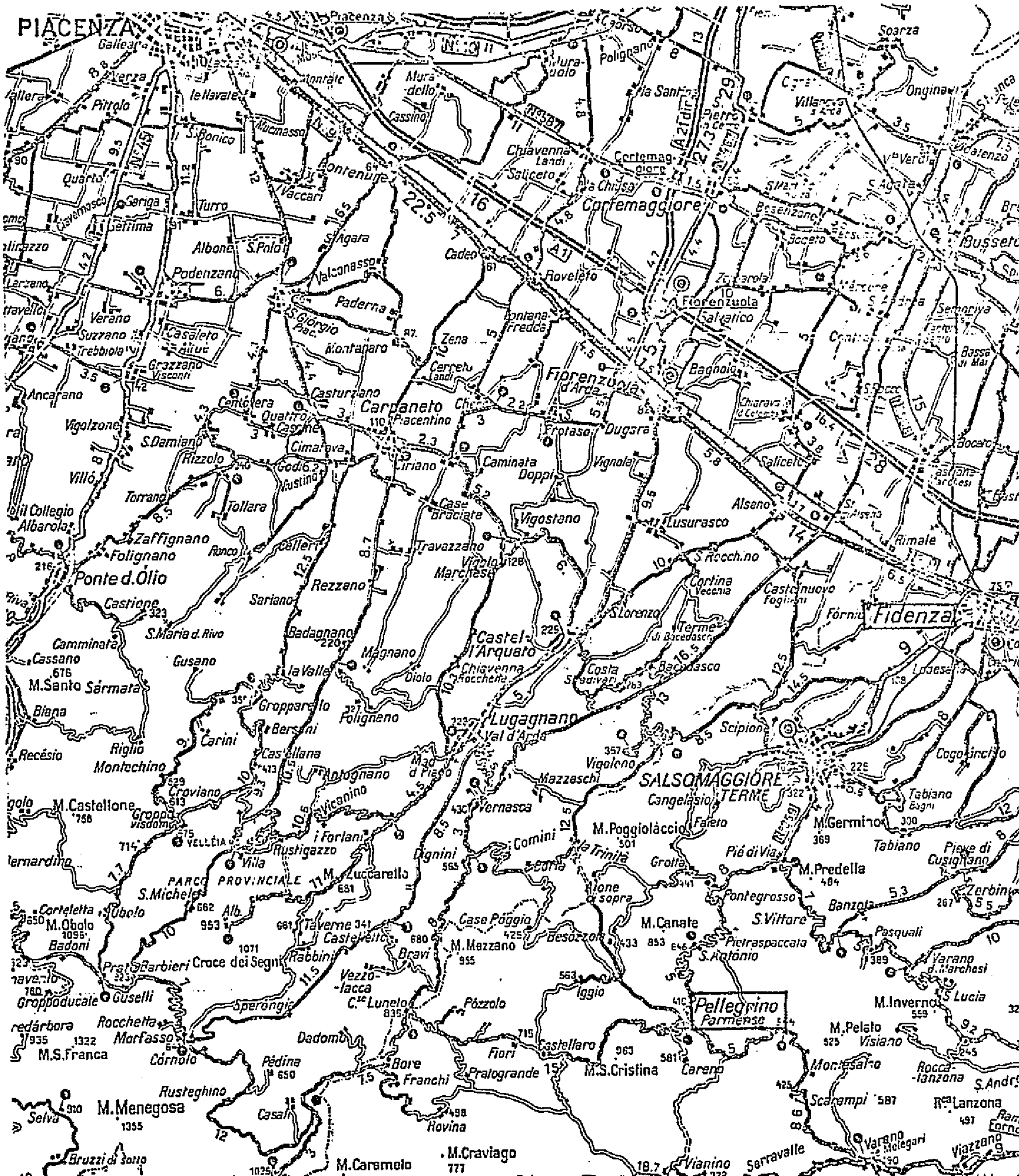


Fig. Ia - Location of the investigated area (scale : I:200.000)

This site was choosen because it is very representative of the different si tuations which characterize the N.A.R. (Fig. I-Ia).
We intend to present now the final report of our work considering a selected area in Northern Appennine Range (N.A.R.) (Fig.2).
Particular attention will be devoted to our effort of choosing some physical parameters able both to quantify the phenomena and, in the meantime, to be detected from Landsat MSS.

METHODOLOGY AND TECHNIQUES

a) Geologic background, geomorphic informations and values.
This study is a comparative analysis which integrates the classical methodology of investigation and the data acquisition by remote sensing techniques.
On the step of the acquisition of basic data the research was enterprised follo wing the classical way of a geomorphological study.
The geological features of the test area have been analyzed utilising the most usual data such as the official geological map and the topographic charts.
Considering the above mentioned information and by two different ground surveys a geolithological map (polarized in geothecnical application) was drawn in order to take into account the permeability value of the outcropping formations.
The different units were groupped following their permeability (due to fracturing and porosity) in a growing order (Fig.3).

Category 1
Clays having a low shrinkage limit. They exhibit a very dense surface cracking in the draught period of the year. In this way the rain water penetration is made easier. Category 1)is subjected to bad-land evolution. The geographycal evidence of the category is confined to a well defined belt facing the Po Valley plane.

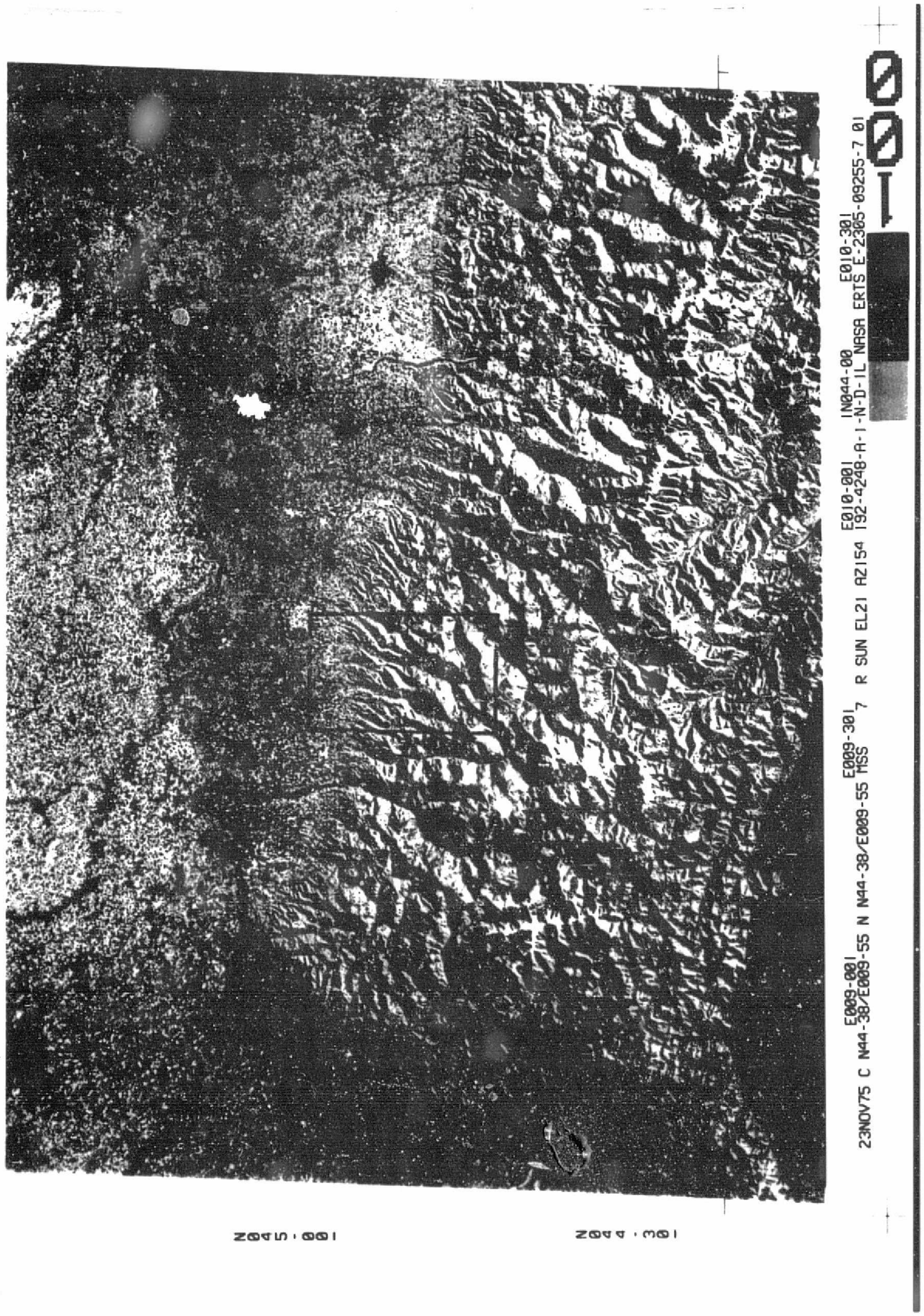


Fig. 2 - Northern Appennines Range as seen from Landsat 2.

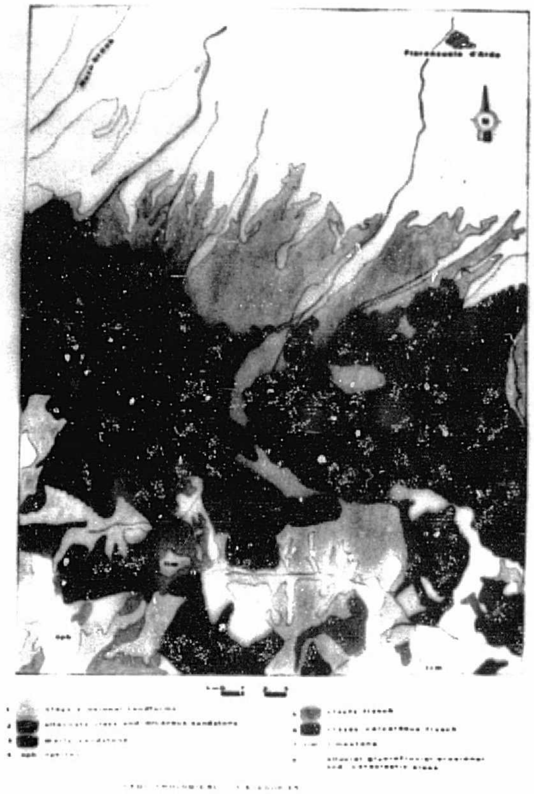


Fig.3 - Geolithological categories.

Category 2

Dense alternation ofshales and micaceous sandstones, Other formations are included in clayey sandstones having the arenaceous layers prevailing in the upper part of the formation,

Category 3

Layers of marbly and micaceous sandstones, Owing to the fact that in this area the arenaceous beds outcrop with calcareous alternations, the arenaceous facies are ascribed to this category.

Category 4

Ophiolites: it is noticeable their competence to the weathering,
A certain level of permeability is present due both to fracturing and jointing, and to the frost and thaw.
These phenomena give rise to debris fans. In this case weathering does not produce any real soil and only a bare soil may appear.

Category 5

Argillaceous flysch; chaotic evidence with highly warped strata and low global permeability. Intense surface rilling due to the clayey fraction.

Category 6

Calcareous-clayey flysch.

Noticeable creeping phenomena in the alteration sheet.

This flysch exhibits an high level of fracturing and tectonizing action. It behaves in such a manner as a permeable medium so that perennial springs can be supplied.

The presence of water table has a negative influence on the slopes stability and gives rise to slipping mainly after Spring and Autumn rainy periods.

Category 7

Calcareous units.

The morphology of this formations shows steep slope relieves that usually are wood covered.

Category 8

Surface alluvial and riss fluvioglacial deposits.

Landslides and debris materials (cathaclastic areas) with rock fragments included in a terrigenous matrix. For the above mentioned characteristics the physical parameters affecting the mechanic stability of these formations are modified expecially after rainy periods or when the winter snow cover melts.

Having as a main goal the complete knowledge of the examined area (by means of classical methodologies) the representation of climatic parameters of 1969 was drawn utilizing the data coming from the Hydrographic Office of Po river (in italian, Ufficio Idrografico del Po)(Table 1).

The interpolation of these data, very few indeed, made possible to define some values deeply related to the extension of seasonal snow cover and the rainfall of this area.

T A B L E I   RECORDED DATA FOR I962 YEAR

order number	recording stations	average temperature value a year (°C)	average rainfall value a year (mm)	altitude	snow cover performance (days a year)	Fournier index $p = \bar{M}_{max}$(mm) $P = \bar{A}$(mm)	Aubert & Hénin index I = (mm); P=(m)$\bar{A}$; T=(°C)$\bar{A}$ $I = \frac{P^3}{P+0.15T-0.13}$	Lang rain efficiency index F = P/T P = $\bar{A}$ (mm) T = $\bar{A}$(°C)	Evapotranspiration index (Le Turc) $E = \frac{P}{(0.9 + P^2/300 + 25T + 0.05T^3)^{1/2}}$
I	Roccolo		I007	9I6	67	23.48			
2	Bettola		873	329	48	30.56			
3	S.Giorgio		744	I04	34	I3.75			
4	Castellana		992	434	46	33.39			
5	Reziano		973	200	46	30.38			
6	Mignano		I046	342	43	I4.93			
7	Fiorenzuola		745	82	44	I2.4I			
8	Nocceto		764			20.76			
9	Cornolo		I354			44.9I			
I0	Pione		III5	675	73	35.78			
II	Bardi	I0.7	969	450	53	29.67	372	90.59	25.07
I2	Varsi		957			39.37			
I3	Varano M.		8I3			I8.47			
I4	Careno		III4	58I	44	28.25			
I5	Salsomaggiore	I2.4	992	I60	52	I5.20	395	79.98	26.55
I6	Fidenza		768			I4.35			
I7	Varano M.		890			I7.05			
I8	Castione		7I7			I4.32			
I9	Ramiola		886	I45	47	26.32			
20	Bovaia		965			I8.48			
2I	La Costa di Majatico		900			I9.85			
22	Valmaziola		978			23.50			
23	Boschi di B.		885			I8.70			
24	Calestano		969			22.80			
25	Selva del B.		9I6	539	66	I7.80			
26	Carzeto		7I3			I0.50			
27	Statto		855			I4.60			

Unfortunately there are not thermal data recording stations on ground and thematic maps are confined both to the analysis of Fournier factors showing the erosional climate capacity and to different rainfall and snowfall description (Figg.4-5).

Nevertheless in three locations inside our test site it was possible to compute also the drainage model values (Aubert and Hénin), the evotranspiration (Le Turc) and the rainfall efficiency (Lang) values. If more data were available so that it was possible to draw these type of representations for the whole area the climatic phenomena which produce landslides had been described with a better accuracy and been related in a proper way to the lithology of the outcropping formations.

Another factor which obviously affects the surface behaviour of a certain area is the sun exposition of the valleys.

The comparative analysis of these arguments (presented by their thematic maps) leads to some interesting considerations regarding the tendency toward a more or less accelerated erosion.

This event is mainly linked to:

a) the lithological factor when the not saturated portion of the soil is affected by noticeable changes upward in the level of the water table. They are clayey and soil outflow by a spontaneous liquefaction of very large areas. However, silt and even sand layers can play a major role in the liquefaction process;

b) the alternate and closely bedded formations, having both pseudocoherent lithologic types and well marked slipping planes with water infiltration inside, also when slopes are not very deep.

The landslides types in the area not only slipping ones but we can define them better like spreading slumps by a sudden movement resulting mainly from a failure in the layers at the base, due to the high pore-water pressure that causes a more liquid movement.

Vegetation is present both as trees in well defined zones and diffused croplands quite every-where.

Alluvial cover is cultivated also in mild slopes; sometimes soils, directly over

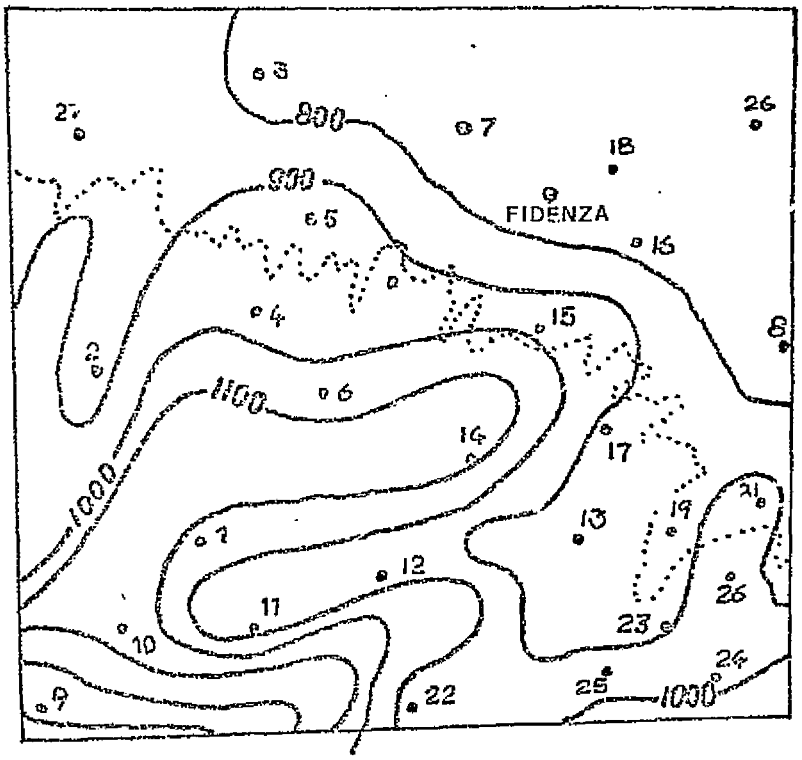


Fig.4 - Location of the climatic data recording stations and annual rainfall value (1969). Scale 1:500.000.

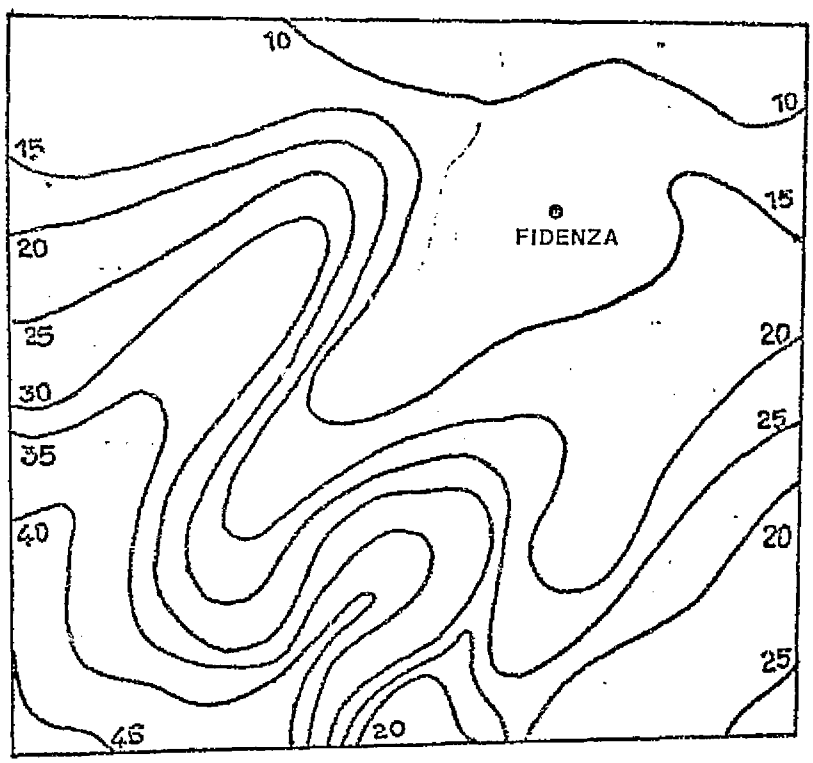


Fig.5 - Distribution curves of the Fournier index Scale 1:500.000.

their bedrock, exhibit only "A" level.

The first order hydrographic network is strongly influenced by lithology so that head water gullies appear in the area having plastic rock types (Fig.6).

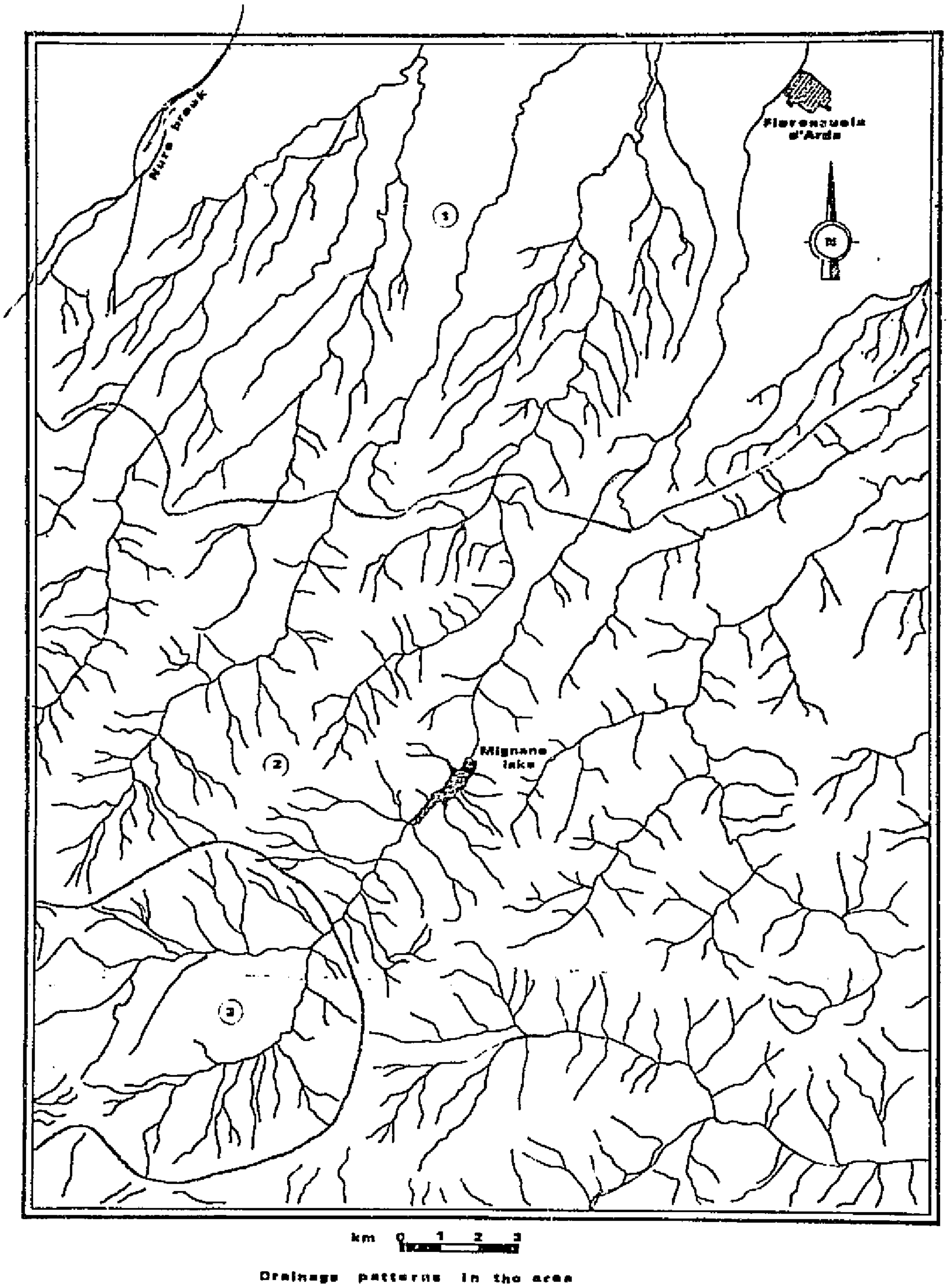


Fig.6 - Drainage patterns in the area.

The close anastomatic rilling systems cause oversaturation in the upper part of second order basins.

In many cases it is easy to note phenomena of regressive erosion, due to piracy, and of interaction between different basins of higher order; this fact is due to the weathering of the watersheds.

The water factor plays an important role in the studied landslide events: the saturation of the most plastic lithologic unitslowers noticeably the value of the limit of slope stability angle.

The sun exposition of the sides is also favoreable to the erosional effect of weather. Vegetative cover is very low and well confined.

Image analysis

As a general consideration , the topography of the test-area well fits with satellite investigation: the shadow effect is not very high and the sun exposition is very good.

Considering the type of our study, after several experiences, we made a distinction between linear and areal erosion also considering the noticeable obstacles we found for the acquisition of a complete discrimination of the spectral signature of the same phenomena.

So far, we prefer to approach our research as an erosional study considering the soil moisture (in the sense of a presence or not of oversaturation in soils) as the main parameter in connection with the flow rate of the main rivers in the test-area.

The relationship between the mechanic behaviour of the considered lithologic types and the map of the erosional capability of climate (drawn of the basis of Furnier index) defines a certain number of areas having a better inclination to erosion. This event happens mainly in NE-SW direction rightly connected with the morphologic and hydrographic regional trend.

The superimposition of shaly-marbly formation to the higher values of Fournier index shows areas perfectly connected with the real distribution of erosional events.

A ground survey was done in order to better define the geologic features of the test area; the ground observations were obviously performed having in mind the scopes of the comparison of these observations with space coming data. Landsat 2 seasonal images are referred to February, June, July, August and November.

N°	Date
2017 - 09280	8 February 1975
2143 - 09275	14 June "
2179 - 09273	20 July "
2197 - 09271	7 August "
2305 - 09255	23 November "

A first selection was done considering the images recording a great activity in the vegetative cover.

The whole work has been mapped in 1:100.000 scale as a best compromise between Landsat resolution and the type of phenomena on study; in fact in our test-site erosional phenomena have a quite large extension,

In order to determine the highest contrasts and the prevailing densities a first analysis was enterprised utilizing false color composite transpariences and prints (1:1.000.000 and 1;250.000 respectively, see Fig.7).

In this way a selection was possible in order to detect areas with more or less vegetative cover, areas which higher or lower level of humidity and wet soils.

The 7 bands and the comparison with the 6 ones have given good data on high ground water table and water content into surface materials (trasparencies scale 1:1.000.000 and 1:500.000 prints).

Among several notations a particular mention, outside the forest trees areas, has to be given to the outcropping ophiolites which are easily detectable for their very high absorption.

Nevertheless the most striking morphologic evidence is the barren belt facing the Po plain, which shows a sudden change in reflectivity value and a marked typical fish-bone texture.

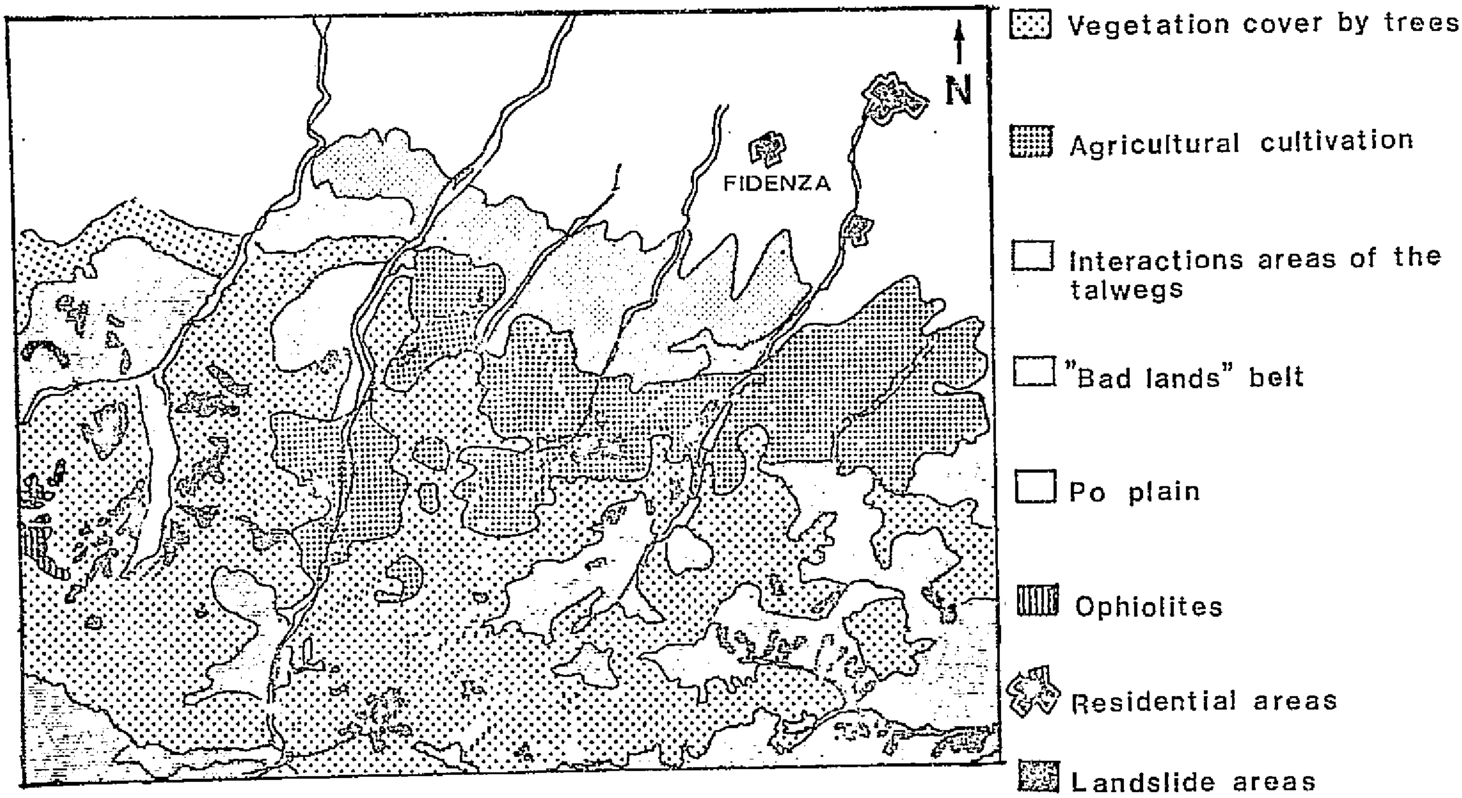


Fig.7 - Densities resulting from the prints scale 1:250,000 false colour composite.

The multitemporal comparison of images gives prominence to the real presence of river beds having few connections with the hierarchy of the streams.
In some cases the evidence of II order streams is higher than the IV order areas, leaving apart obviously topographic considerations.

Image processing

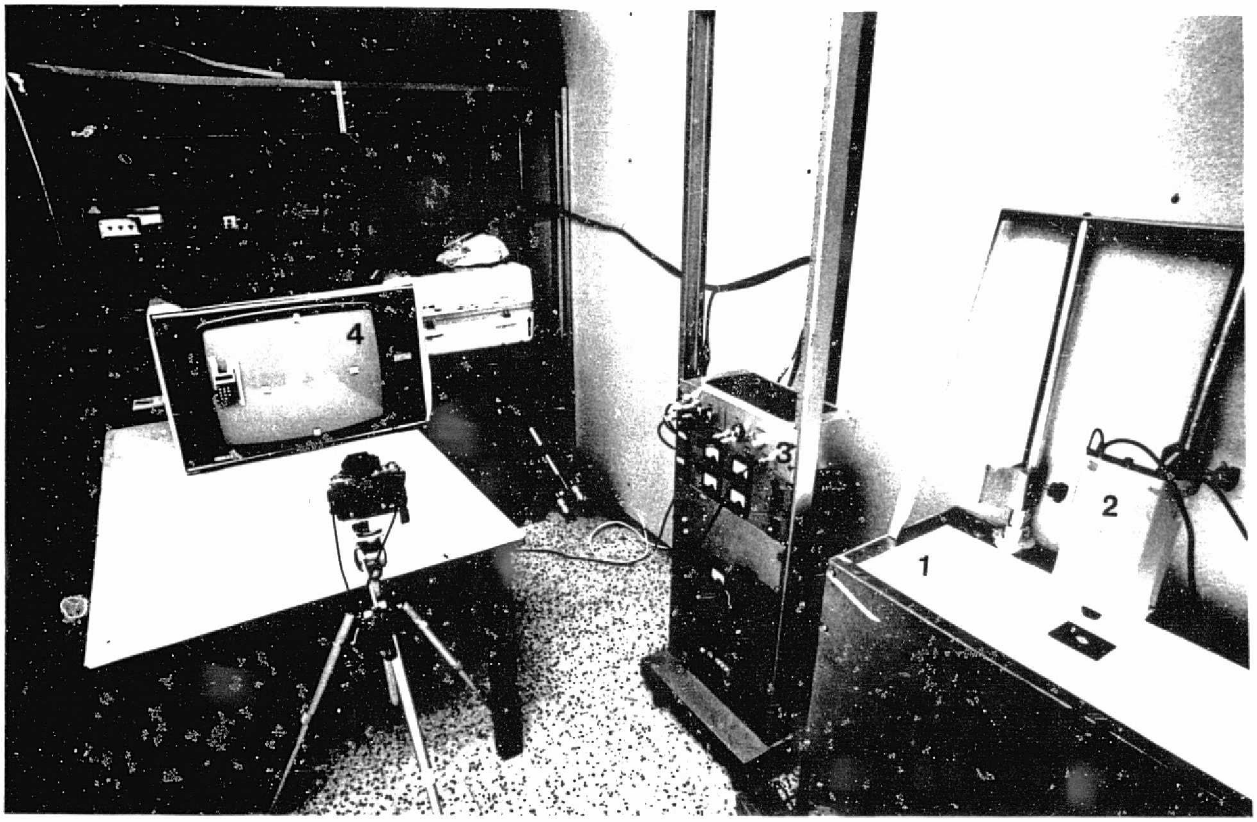
Trasparencies (1:1.000.000 scale) were analyzed by means of one image analogic analyzer (prototype built in our research laboratory) in order to define the best processing for the purpose of the work (Fig.8).
Our color TV analyzer is able to perform the following analogic operation on the

signals (Fig.9).

a) normal derivative function

b) absolute derivative function

c) slicing



I - Light table

2 - T.V. B.&W camera

3 - Derivative function -Amplifier -gain- and offset control-Six level slicer- Color encorder.

4 - Color display (Slave monitor)

Fig. 8 - Configuration of the machine processing.

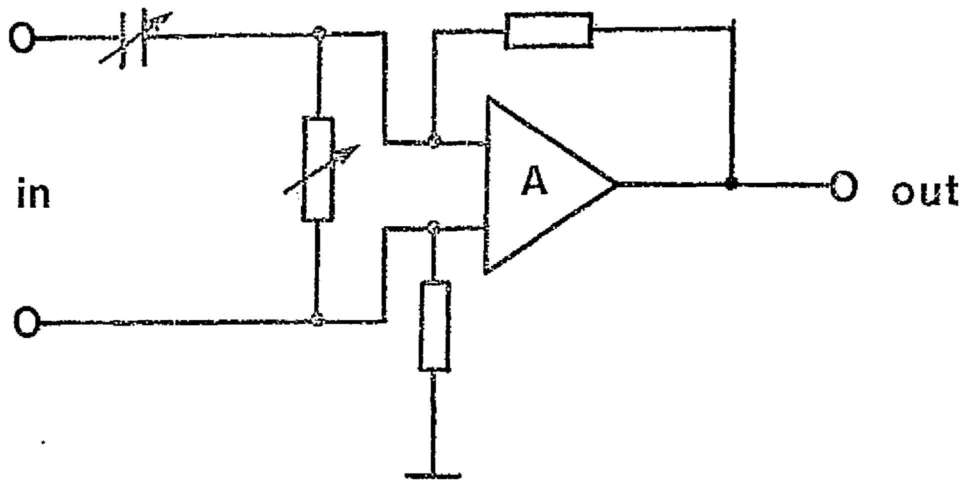


Fig. 9 - The derivative function circuitery with the suitable amplifier.

These operations can be done also in combination (example: slicing of absolute derivative). The selection of the best passages has been made in order to discriminate:

- the highest physical contrast of barren soils; dry and wet ones
- the lowest vegetative cover noise.

The more significant images in this sense have been taken in winter periods but also the June informations have appeared very interesting where suddenly we can see a correlation with the geolithological behaviour.

Other processes (photographic sandwiches) have been made for temporal and spectral analysis.

The best expression of the masking have been:

- spectral ratio between 5&7 bands-June (Fig.10).

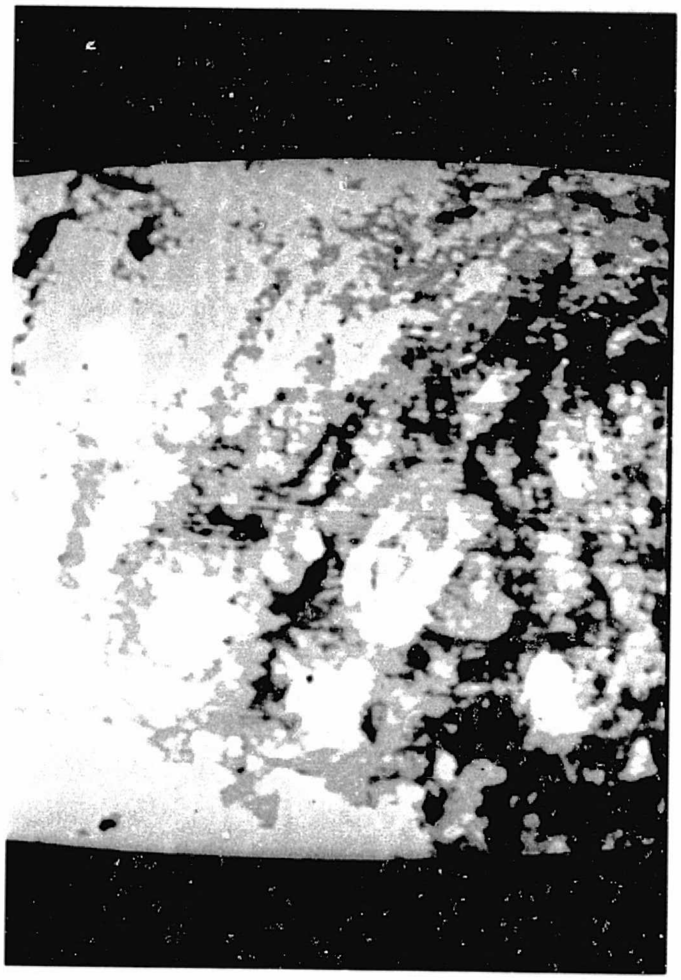


Fig. 10 - Slicing of the ratio between 5&7 bands of June.

- spectral product (MSS 6&7 bands) - November (Fig.11)
- " " - August (Fig.12)

The electronic slicing of the first expression produces the better relationship to the geolithological maps.

For this reason, we can suppose that a close relation should connect vegetation cover with geology; the first event is due to the different infiltration values of surfi cial rilling waters and to the various absorption speed due to the low thickness of

Fig.11 - Derivative enhancement of the product of bands 6 and 7 in Winter images. We can easily distinguish the texture of the area and the different three zones from the top:
- Po Plain
- Bad Lands, close hydro graphic pattern and low permeability of the rocks
- The Appennines range foothills.

Fig.12 - Derivative enhancement of the product of bands 6 and 7 in Summer images. The presence of a noticea ble vegetation cover is snown by the expansion of the green level in the pic ture.

the eluvial soils.

The erosional and bare areas are summed up and expressed by similar densities.

In this elaboration it is interesting to note the high reflectivity value of trees and vegetative cover (in general) and also the low humidity content at the surface.

The setting of this slicing is very particular (4 levels and very narrow discrimination windows) so that river beds are not well evident.

The photographic products have been derivated following the above mentioned way in order to give a better prominence to three morphologic belts:

a) plane

b) barren soils (bad lands)

c) hills

The texture having NE-SW direction is emphasized by the aligment of ridges and their shadows.

This type of elaboration is very useful to define the different humidity content of the examined areas which include exactly the zones subjected to sliding due to oversaturation of shales and to different water-soil interaction of talwegs.

In the elaboration of the image of the Summer period both a reduction, from a geometrical point of view, of these areas and an increase of the vegetation response shows up.

Moreover it is noticeable in band 5 the fast drying of shales, in draught periods, which gives rise to an high reflectivity value.

At this step we have to mention that the analysis of the image elaborations was performed after the selection, utilizing official geologic maps, of the areas more evidently prone to landslide phenomena (Fig.13).

Areal extension of our study

The extension to the conterminous areas of the categories determined in this way needed a ground confirmation.

For this reason a survey was performed regarding those areas exhibiting a similar

spectral response in order to define the real power of this kind of approach.
The ground survey testified the continuity and a real possible areal extension of these results, always having in mind some needs of a previous data filtering on a local basis. Fig.11 better explains this latter question.
The dense mosaic representing the plane includes several fields having both different culture coverage and variable water content.
In this way a spectral response about similar to the one interesting the areas on study may appear and this event could give rise to a misunderstanding in the interpretation step.
In other zones our control shows similar response for the earth outflow of the agricultural soil and/or the eluvial cover, expecially when the water content is so high that not only the above mentioned phenomena may appear but, sometimes, also the shaly or marbly bedrock may flow.
Also in this case a correct approach to the problem is needed considering that the spectral signature is not meaningful when several are the parameters that describe the whole phenomena and their relationship may appear in the images as only one spectral category.
In our study the differential absorption (function of humidity content of bare soils) was choosen for mapping the areas of interest.
Obviously we had to consider that the change in the reflectivity of the surfaces also depends on:

a) detectors look-angle cosine
b) granulometry of geologic formations
c) presence or not of vegetative cover
d) atmospheric transparence (as in the example of June).

SUMMARY AND CONCLUSIONS

As we mentioned at the beginning of our report in "methodology and techniques" this study is a comparative analysis of Remote Sensing techniques and data coming from the classical methodology of investigation. The comparison between these two ways of research gave rise to some new knowledges in the investigated area.

In this framework the use of previous data such as the climatic and the topographic ones was very important but only in order to have a general view of the characteristics of the area to describe and to limit large zones in function of the most potential erosional efficency due to rainfall and meteoric events.

The representation of climatic parameters, inferred by morphologic formulas have been compared each other to define the areas where the effects summed up, in this way increasing their erosional power, but the distribution of climatic factors has not given relevant contribution to limit the real landslide areas, except the climatic erosion capacity of Fournier that follows well enough the weakness lineaments along the valleys, with high values persistence where the most erosional effects can be seen easily, both in "bad lands" formations and in the test site.

In this way, an immediate comparison with the geolithological map is to be considered to increase the accuracy of this part of the work in the field of mapping the potential landslide areas.

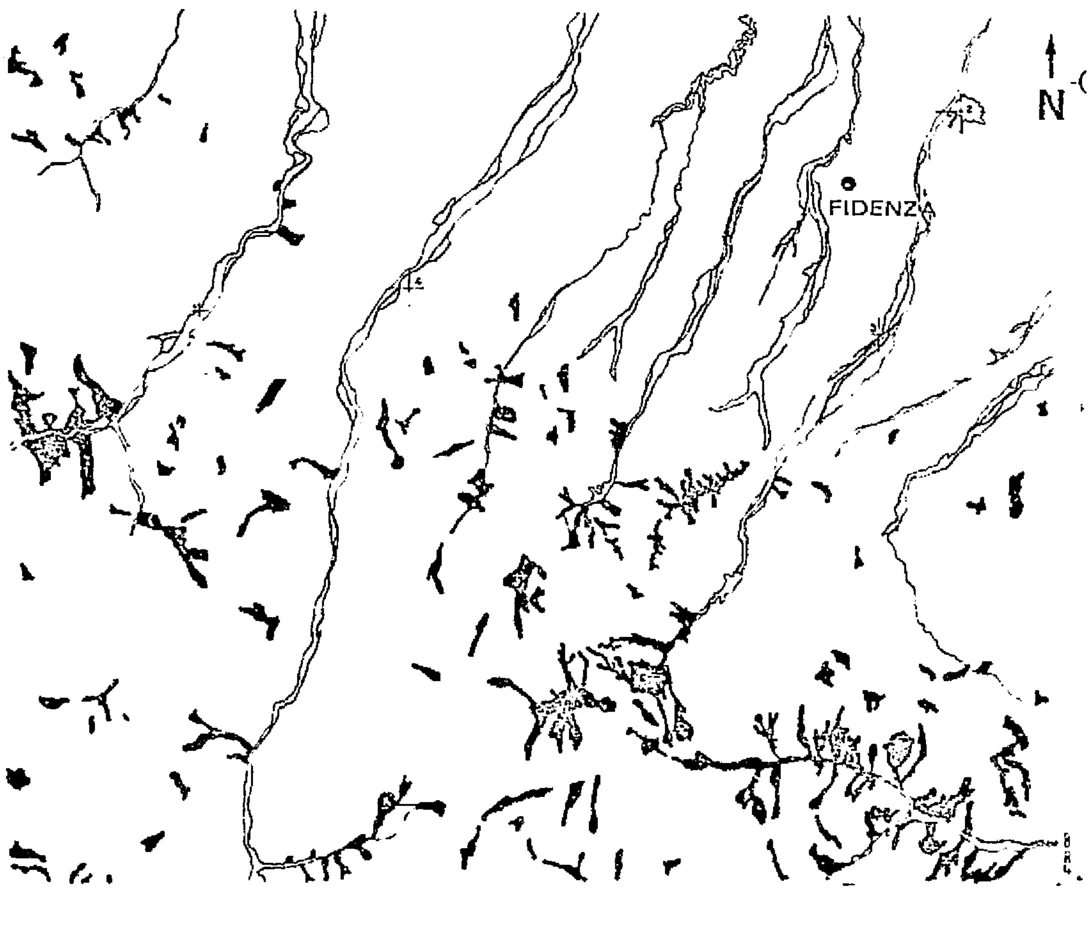


Fig.13 - Landslides map from the geological sheet by I.G.S.

The Landsat information was then utilized following these steps:

- Identification of the high moisture soils (see pag.19), it has to be noted the good results obtained from the correlation of landslides field maps with Landsat data where the most important erosional phenomena were detected and identified.
- Following with time the spreading of these areas. This was done in order to reach a better knowledge of their interaction with the neighborning agrarian soils and to establish, during a time span of one year, the set of the upper surphace in terms of different saturation. As mentioned before this part of the study met a good solution and we were able to distinguish many areas having similar behaviour utilizing Landsat MSS images.

  From the analysis one conclusion suddenly comes out, and regards the useful tool of the Landsat imagery to have a general vision of a territory from the point of view of its physical surficial characteristics so that we can follow the narrowing and the expansion of certain areas (Fig.14).

  At this stage a particular attention has to be devoted to the consideration regarding Landsat images elaboration:
- The standard single MSS band does not give a clear representation (of these phenomena) such as the employed enhancements, also for areal mapping purposes.

  The best contrast among the densities has been obtained by product masking of 6-7 bands and related derivative elaborations.

  Nevertheless a great problem remains, i.e. the connection, during the analogic process, between MSS images and their elaboration with topography.

  For this reason the meaning of the work has to be found in areal and regional direction better than, obviously, in a very detailed mapping of individual landslide phenomena and, in this sense, some large areas showing the same behaviour of known earthflows were identified as earthflows unmapped before.

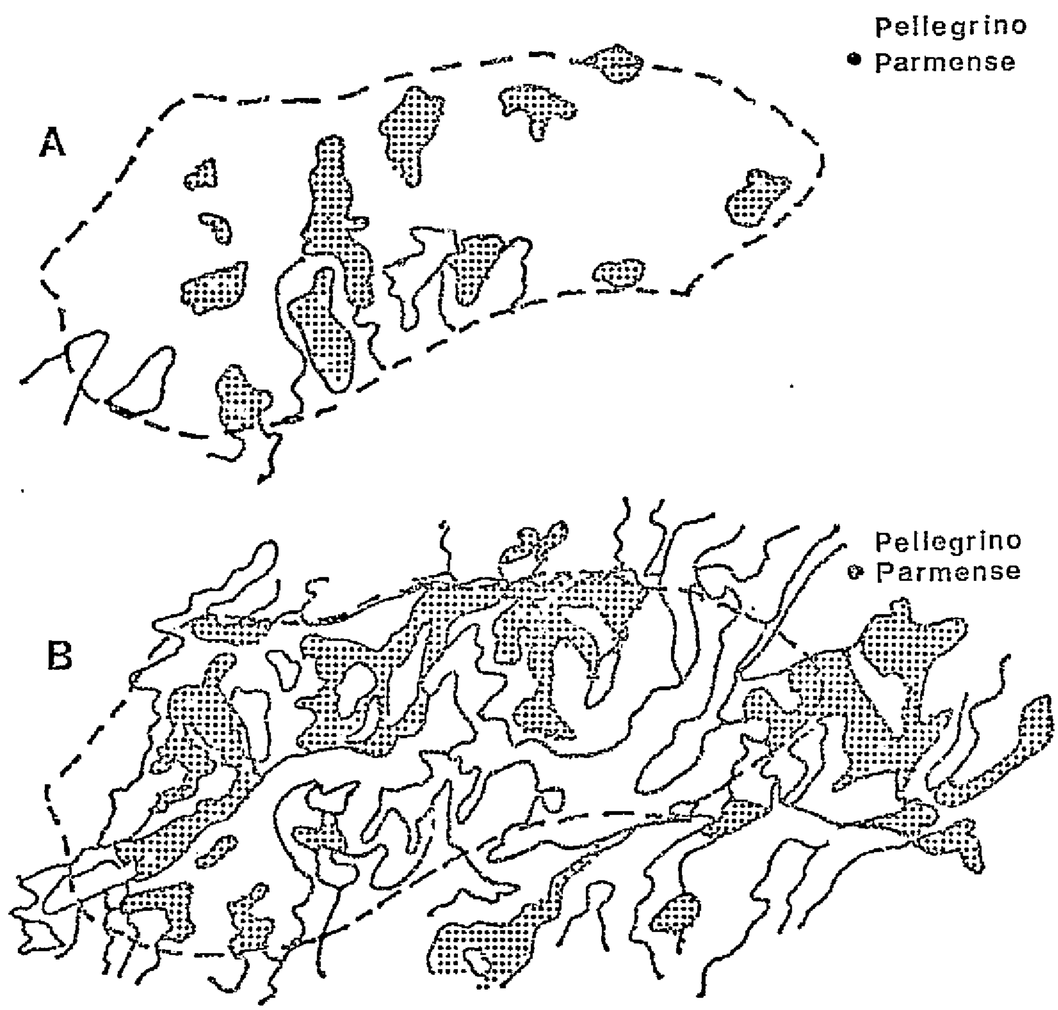


Fig.14 - The test-site basin area.
The plotted spots mean barren soil oversaturated in clayey formations.
A very interesting observation is the narrowing and the different expansion of the areas within the two maps.
Above we can see the summer image where the smoothing of the vegetation eliminates many categories which appear, on the contrary, in winter time (below).
Scale 1:150.000.

APPENDIX 1

Runoff variations of large rivers on the basis of Landsat II images: Po river.

This work was done in the first stage of our research in order to familiarize with some characteristics of the Northern portion of the surveyed territory. The study was divided in two major topics:

a) Hydrographic network mapping of Appennine rivers
b) Runoff variation of Po river.

a) Hydrographic network mapping

The mapping was accomplished utilizing 1:250.000 prints of different bands and Landsat II passes.
In detail MSS band4,5,7and false colour composition of these bands were studied regarding the Northern part of Appenninic Range facing Po river valley.
The three Landsat II passes are between June 14 and July 20 (year 1975).
Image numbers are: 2179-09273; 2143-09275; 2197-09271 and 2017-09274.
The significant results identified by this analysis are based on the principal hydrographyc characters of the main rivers of the area,
In fact affluents coming from North have an all year runoff typical of Alpine rivers whilist the affluents moving in South to North direction (Appenninic) have a seasonal behaviour typical of creeks.
Utilizing Landsat II images we noted that for the purposes of hydrographic network mapping is not possible to employ a single band (7 for istance).
In fact band 7 is not useful quite completely in revealing large creeks where the reflected energy is due mainly to the response of the bottom of these alluvial rivers,
In fact in these rivers the water runoff is not very poor only in spring-time or after rain storms.
The maximum of the spectral response due to local geology of the alluvial areas lies between 0.5 and 0.6 micron and so pertains to wavelenght of MSS 4 band.
For the above mentioned reasons both 4 and 7 MSS band were employed in order to trace a hydrographic network sketch map.

b) Runoff variation

In order to have reliable data on the possibility to follow with time the Po river runoff we compared the streamflow width variation as seen from Landsat II images with river hydrometric variations in some fixed places,
Basing on the data recorded in the same days of Landsat II passes it was possible to build up a diagram of hydrometric height variations in Piacenza and Beretto (two towns placed) on the river shores: the first far and the second close to the mouth) Fig.A-B.

A second diagram was draft from a detailed study of the water covered section (cross section of the river) in the same areas of the hydrometric stations (Fig.C-D).
The following charts well show this relation where the continuous line represents the height variation of the streamflow (values can be read on the left y axis) and the dashed one performs the width amplitude as seen from satellite imagery (values can be read on the right y axis).

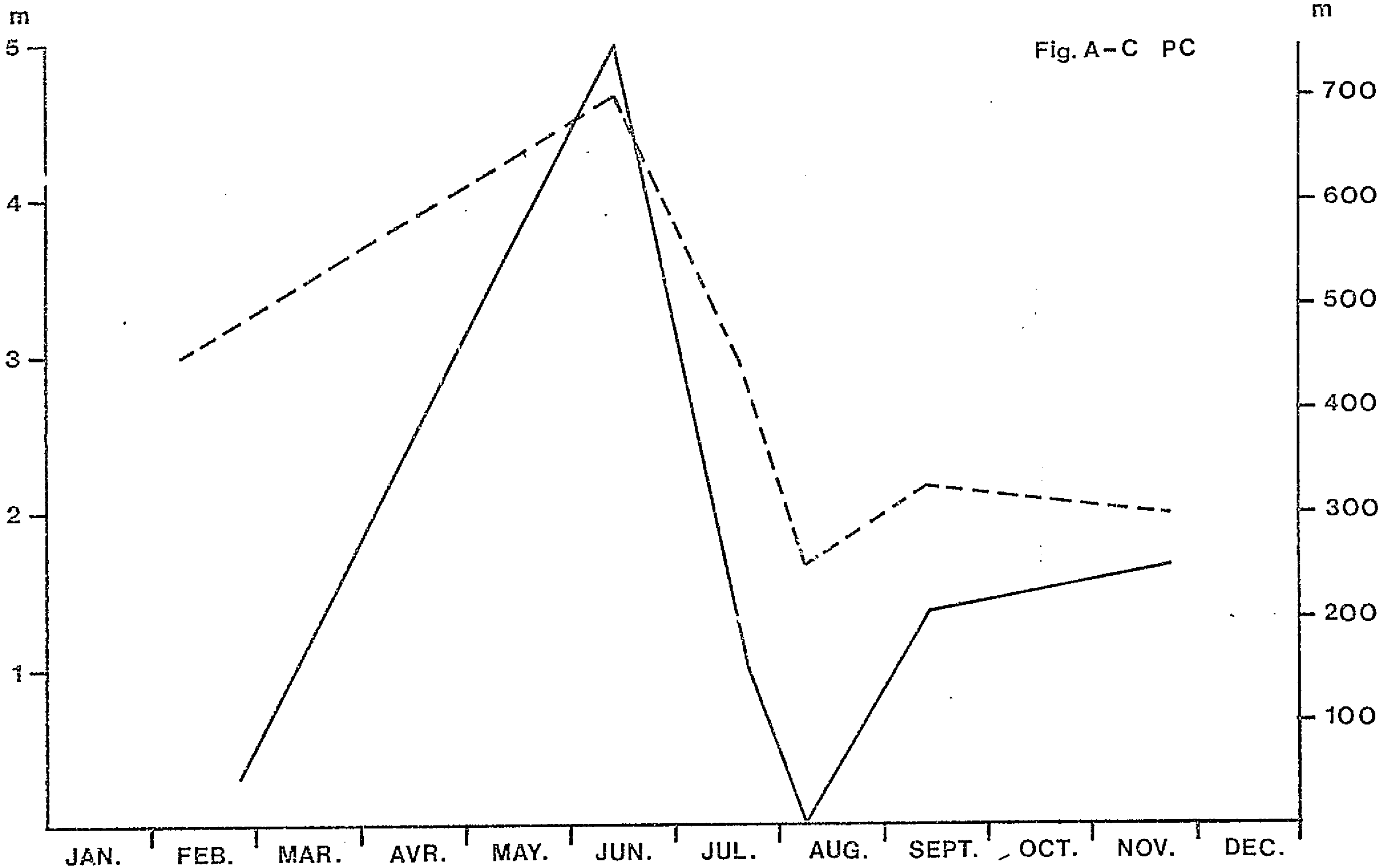


Fig. A–C PC
m
5
4
3
2
1
m
700
600
500
400
300
200
100
JAN.
FEB.
MAR.
AVR.
MAY.
JUN.
JUL.
AUG.
SEPT.
OCT.
NOV.
DEC.

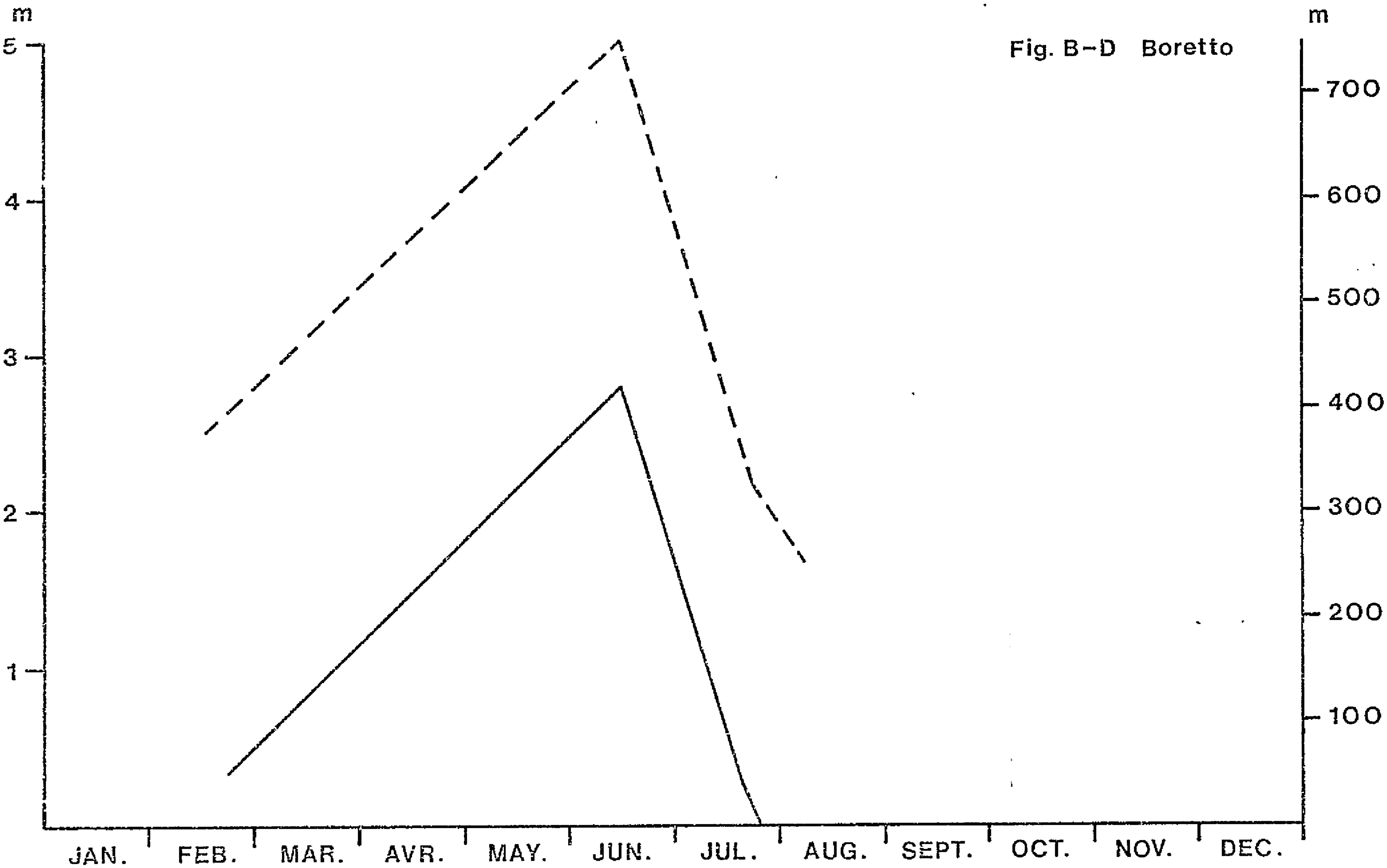


Fig. B–D Boretto
m
5
4
3
2
1
m
700
600
500
400
300
200
100
JAN.
FEB.
MAR.
AVR.
MAY.
JUN.
JUL.
AUG.
SEPT.
OCT.
NOV.
DEC.

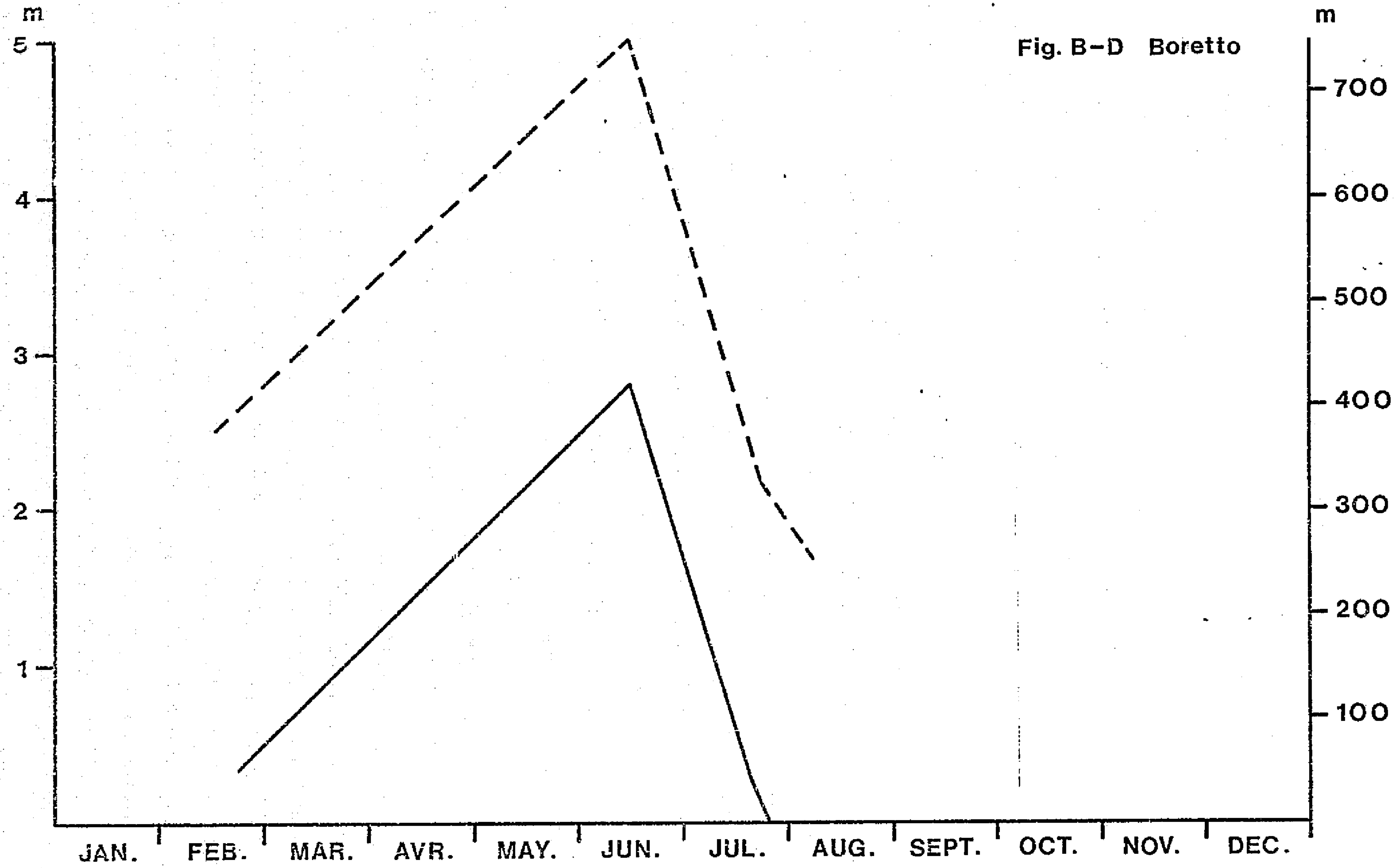


Fig. B–D Boretto