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THE ROLE OF PHOTOGRAMMETRY IN THE TIME ASPECT OF GEOGRAPHIC INFORMATION SYSTEMS

A. Castagnoli, Consorzio Compagnie Aeronautiche, Parma

I should forewarn that this contribution is related to Geographic Information Systems specifically applied to the environment and has the purpose of finalizing a few concepts derived from the experiences that I will illustrate and that I deem of interest.

The use of time as a fourth dimension in Geographic Information Systems stirs interest, has received notable contributions lately (1), and is a must for the effective application of these computer based techniques beyond the more limited applications of digital cartography and CAD systems which, often, have been proposed as GIS with intrinsic and obvious limitations.

For a description of the concept of Geographic Information System I refer to a definition by the US. Federal Interagency Coordinating Commitee on Digital Cartography: "a Geographic Information System is a computer system designed to allow users to collect, manage, and analyze large volumes of spatially referenced and associated attribute data" (2).

I use and share this definition of "computer system" but I like even better the following used in a clear and synthetic contribution published in Italy on this subject (3): "organized system of numerical geographic data, possibly fourdimensional, connected with appropriate computer systems for their acquisition, treatment,analysis and presentation".

I agree in particular that the data must be referenced in at least 4 dimensions: three relative to their localization in space and the other in time so as to best fulfill what I think is the fundamental role of a GIS: support to knowledge and decision making.

Furthermore the temporal reference can be "at a point" but most often, for environmental events, is tied to a duration which, usually, is expressed as a time series.

I am especially convinced, in the above definition the equal footing given to organized data system computer system and data acquisition and treatment.

Aerial photogrammetry is particularly suited to contribute to the time referencing of geographic data for the intrinsic characteristics of the photographic instrument which can offer, in succession, "frozen" images of time referenced situations measurable in quantity and quality and rich in raw information; an ideal condition for maximum content extraction.

Each successive operation or transformation of data in designs or concepts, if it has the virtue of generating semplicity, it has the drawback of making unavailable the source information.

We have a different situation with historical cartography which, because it lacks a "realistic" support like the photograph, proposed to offer conceptual and topological information with a strong visual appeal. Even beyond the intentions of the cartographer, the relations among the signs that he has

1 - In this respect, particularly interesting are the acts of some symposia among which I think one should cite the GIS-LIS and the Global Natural Resources of the IUFRO-FAO besides the myriad of international meetings that annually take place all over the world.
An information support of particular interest is the International Journal of Geographical Information Systems.

2 - FICCDC, A process for evaluating Geographic Information Systems, USGS, Open-file Report 88-105, 1988

3 - PACE, G.B., Cartografia numerica situazione e prospettive, Atti del Convegno Nazionale A.I.C. in Firenze 1989, Bollettino AIC 75-76, 1989.

drafted to make his work meaningful, as well as place names and their hierarchy reveal a reality of enormous interest for understanding the land, the environment, the culture, and the economics of the times.

The value added of historical cartography is its potential to make geographic the great quantities of data contained in the historical texts (notary papers, travel notes, literary texts, ordinances and proclamations), in the arts, and in oral traditions.

The sense that I give to historical cartography as a survey tool for environmental dynamics is thus, mainly, that of analysis of the image it conveys. This cartography permits the patient work of mosaicking the information contained in the archives: to know the past is indispensable to model future scenarios through the very use of GIS. Wherever we have aerial photos we may simply give to the raw content of the photo, trough orthophotographic techniques, a geographic reference to every single event and object with a precision determined by the resolution of the aerial photography.

This technique, together with the innovation in the field of image memorization, elaboration and management (4) opens a vast window on the future that space remote sensing appears to guarantee and that remote sensing from aircraft already provides (5).

The use of photographically based cartography forces us to think back to the past to understand how the vectorial forms we use have become established and if they, today, answer our specific need for geographic information systems that are environmentally oriented.

I think I can exclude it because I don't think they can be based on representations rooted in tradition for various reasons.

For example, environmental events escape the cartographic concept of scale because their dimensions are not always correlated with a corresponding spatial dimension; furthermore such events would need new symbolic forms that express and contain the concepts that is necessary to evidence and map. Too, their representation can only be dynamic. Not a single thematic map then, but the portrayal of processes (that eventually can be documented in time and space by a successive series of thematic maps) and, moreover, the relationships and the tendencies of the processes themselves.

This synchronouos and multitemporal need of the analysis brings us back to geographic cartography based on prospective and the landscape that preceded the present cartography based on vertical projection, bidimensionality and standardization.

I think that environmental cartography is essentially a landscape cartography in that it is on the landscape that the wrinkles of time appear to be analysed, singularly and in multiples, as a product of the whole and of individual factors.

Conceptually we need to consider the land in its entirety and complexity keeping in mind two aspects apparently in contrast but in reality integrated: the global landscape intended as biosphere or noosphere and the complexity of landscapes in their historicity.

Each local landscape is both condition and effect, in the same way that the global landscape is conditioned mainly by the activity of man.

It is in this context that the history of the land takes on its present worth and becomes a possible verification of our forecasting models. Because of this a revaluation of geography is essential in that

4 - In this field, besides some application on hardware by Silicon Graphics, in particular as it concerns stereoscopic vision, I think the accomplishment of Photoscan ZEISS-Intergraph is significant because it provides, numerically, a raw data with characteristics that can be assimilated in resolution to that of the photographic support.

5 - In particular the reference is to the acquisition techniques of SAR and SLAR which, especially for obtaining data in areas not favored meterologically or in catastrophic emergencies, already provide today reliable data and can assist in the normal aerophotogrammetric techniques.

the relevance of the meaning and of the relation of the signs precedes and determines their metric representation in the same way that the visual aspect transcends conventional representation and tridimensional vision transcends altimetry and contour lines.

The primacy of topographic vertical representation became effective at the end of the XIX century as it separated, neatly, the scope of landscape representation from that of the terrain. The prospective technique appeared indispensable for the landscape, symbolism and verticality for the terrain.

In this concept of prospective equals realistic and artistic vision, topography equals synthetic symbolic and scientific vision, we may have some doubts and disagreements because, as Panofsky has exemplarily demonstrated (6), prospective, a technique for the artificial vision of space, is no doubt symbolic. By reason of those observations we can clearly see that the real and fundamental difference between landscape representation (artistic) and topographic representation (scientific) is not merely a concern of the form of the projection but is strictly relative to the concept of time that they underlie.

Landscape representation is rich in details that enhance its temporal punctuality; topographic representation, as it took form through cartography, is detached from its punctual origin, attempting to be lasting and exaustive, anchored in the simplification of reality to exhalt its more persistent aspects with conventional projections and symbolism like morphology, buildings, and cultivation boundaries.

And it did succeed for about a century, until social and political dynamics produced a formidable transformation of the entire planet even in its most lasting components.The map of the Guastalla area in the Po valley, in the next page, goes back to before the war (7). Today it is only a useful support to the knowledge of landscape archeology. A comparison with preceding maps, even 100 years older, (8) makes possible the recognition of places, the essential clarity and logic of urban and road development, the substantial persistence of sight. But observe, for example, the 18th century print that portrays a bend of the river (9). Try to compare its information content about the environment, man's activity, and the tools in use. The information that emerges, even in the simplicity of the representation, is very vast and useful to formulate synthetic judgments about the environmental quality of that landscape, its economic use, etc.

A comparison with the recent cartography of (10) and with a recent photograph (11) demonstrates how transformation continues, swifty and expanding, and how by comparing map with photograph, the latter (possibly stereoscopic) possesses maximum information wealth concerning the present and the remote landscape.

Anyway the ideology of the "snap shot", typical of the photograph, is directly imitated by art and "artistic" were considered the works of the old cartographers.

6 - Panofsky, E., La prospettiva come forma simbolica e altri scritti (1915 - 1932), Milano 1961.

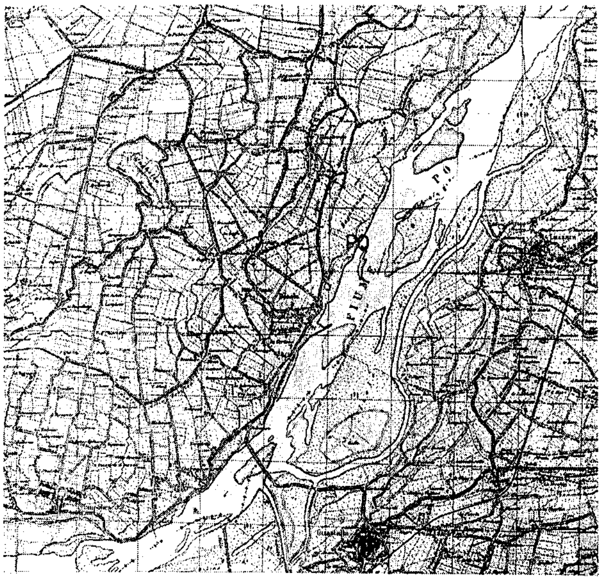
7 - Istituto Geografico Militare Italiano - Tavoletta 74 IVNE, 1933.

8 - Carta Topografica dei Ducati di Parma, Piacenza e Guastalla, rilevata per il governo dell'Arciduchessa Maria Luigia negli anni 1821 - 1822 e stampata dall'Istituto Geografico Militare Austriaco in Milano, 1828.

9 - Sanguigna di J.F. Revenet, sec XVIII, archivio di Stato di Parma.

10 - Carta Tecnica Regionale della Regione Emilia Romagna, Sezione 182080, scala 1:10.000.

11 - Photo of June 1988, scale 1:75.000 volo ITALIA 88/89 - Consorzio Compagnie Aeronautiche - Parma, Conc. S.M.A. n. 1124 del 27/09/1988.



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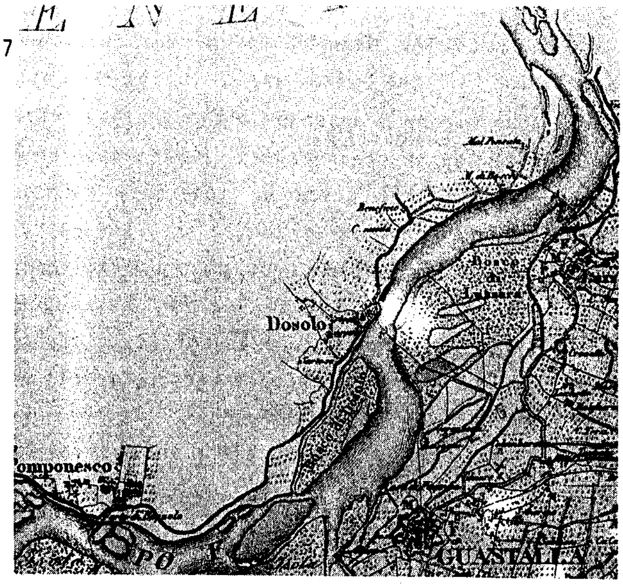

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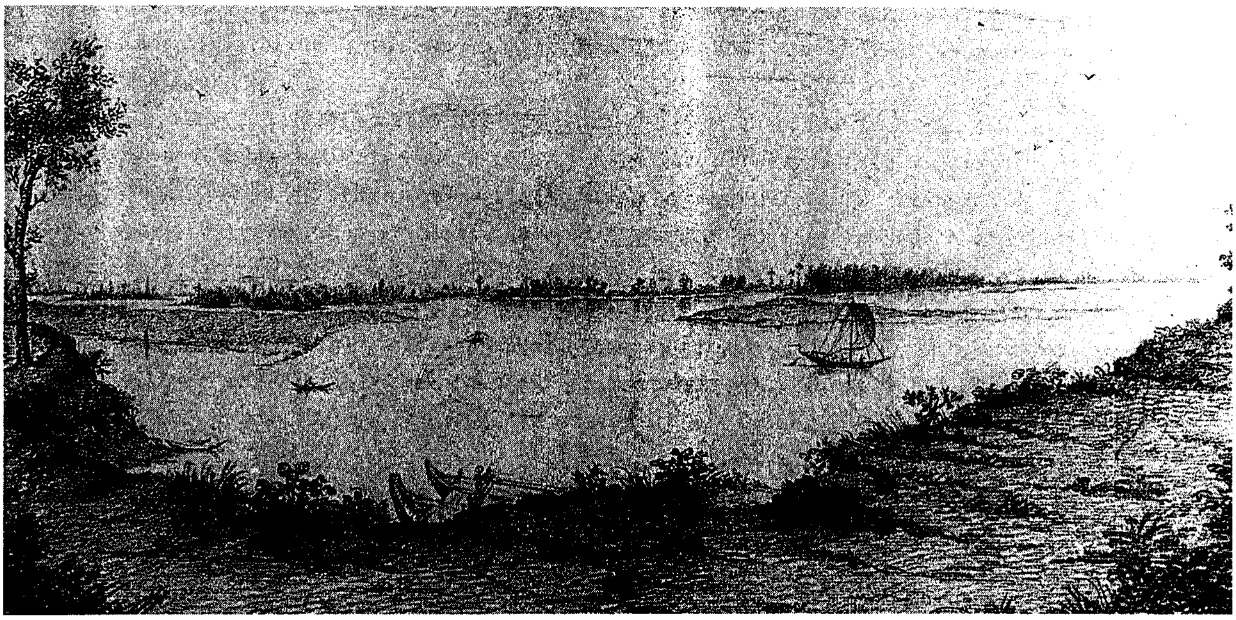

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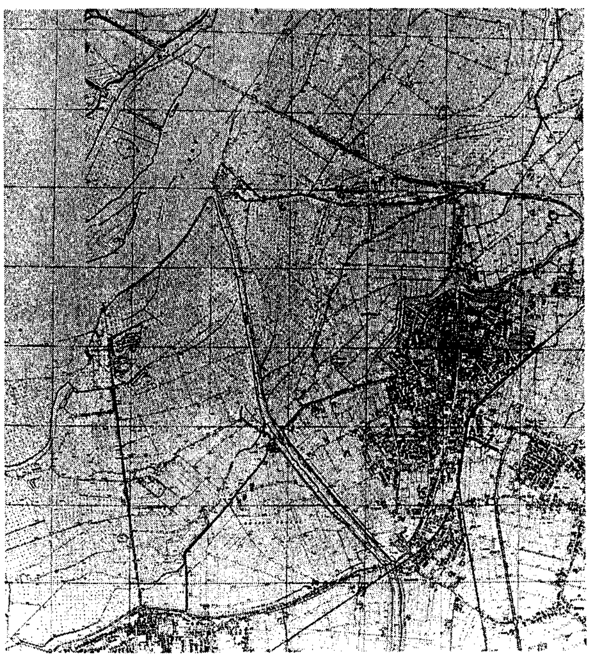

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The use of photography in modern cartography, as it did develop, was determined by a logic outside the instrument itself that only saw its use as a worthy technique subordinated to its decoding by the upcoming photogrammetry. Important documents on this emergence and specificity of cartography as a "science" and its detachment from "art" are the 19th century norms developed for the preparation of national maps (12). These, anyway, were the products of the needs of an epoch which, from the Napoleonic dream and the complementary alliance of the monarchies, through the industrial development and the use of the engine, express, contemporaneously, a clear determination to territorial possession and an immense demand for engineering. And, in any case, until the coming to the forefront of applied ecology, all ideologies and the very religions of the west have expressed, each in its way, the same strong need in the conviction of a development and a linear progress that considered human activities as a closed system in a field of unlimited resources.

Today we know utterly well how concrete is the opposite, that is that we have an open system and limited resources: the second thermodynamic law that determines the concept of entropy.

It is into this problematic picture for men of our times that we sum up the indispensability of the "artistic" aspect of relief, that is determined in time and in its most complete and least decoded form. The measurements that we need today are not only meters, be they squared or cubed, of the earth surface and of the infrastructures, but also linear, square or cube meters of entities such as biomass, the carbon cycle, the eutrophic state, solid deposition, acid emissions, evapotranspiration etc.

These are often measured on the basis of "threshold" values, the product of empirical experience of applied sciences, and of political mediation. Statistical elaboration of decoded information may help but, to understand, document, and model the events, we need their spatial and temporal reference.

There is a branch of applied ecology that is developing well: landscape ecology (13). Like all branches of knowledge of recent birth, non strictly tied to a technological process or to a special instrumentation, it was born and has developed not uniquely, also and above all, because of the different background of its students. It appears to be particularly fitted to address systems that have as objective the verification and the measurement of landscapes entropy, thus of their components and relations. The metodologies described here were born of this approach ten years ago. They have developed alongside the ever more evident needs in this field, in the availability of hardware and adequate techniques (high altitude and high resolution photography, new generation work stations, analytical instrumentation for aerial photogrammetry) and in the development of software for computation, animation, tridimensional vision, management of images and of topological and relational data bases.

Three coordinates for space, one for time, and the image: these are at the moment the ingredients for an environmental geography that by the use of information science may answer the needs of contemporaneosness, taking into account that, having opened the door of the fourth dimension, the multidimensionality of information systems will be (and it already is) the order of the day. The role of photogrammetry has been rethought within the conceptual scope already described, with the aim of

12 - Of special interest is the documentation whose synopsis is given in the bibliography relative to the commission of 1802 for laying out the cartographic standards in Paris at the War Ministry and, for Italy, the official report that accompanies the law for the preparation of the topographic map of Italy (1875).

13 - The term Landscape Ecology was coined by the biogeographer Troll back in the 30 ies.
The IALE (International Association for Landscape Ecology) is active since 1982. The bibliography is extremely vast and not homogeneous so that I have not used it for this paper. Please consult the Landscape Ecology publication, and the acts of the meeting "Prospectives in landscape ecology" (1981), Wageningen, 1982, where the IALE was born.

finding in this technique significant supports for the preparation of environmental GIS.
To illustrate an activity in this direction, I introduce a description of an EUREKA project recently started by an Italian public-private consortium (CISIG: University of Parma, IBM SEMEA, Consorzio Compagnie Aeronautiche) with Spanish partners (Autonomous University of Catalonia, IBM Spain). The title of the project is GEOKRONOS ENVINET EU 516 and its technological finality is the set up of four dimensional GIS and the use of images which are rendered geographic and amenable to 4D modelling; the cultural ambition is to insert history and man's culture in the management system of the environment.
This project initiates from the great potentiality of a general aerial survey of Italy conducted in 1988/89 by the Consorzio Compagnie Aeronautiche at high altitude (12.000 m) with high resolution cameras and films.
This synchronous and homogenous areal survey represents the temporal starting point and it can be considered a single image in 5000 stereomodels of the entire country with a resolution of about one meter.
The principal concept underlying the project is related to the cultural role that has the image as the source of information.
The existance of techniques that lead to geographical images with cartographic precision is thus the road undertaken to maintain this informational aspect even while digital manipulation of the information is undertaken in depth.
A technique has been developed for data acquisition to construct DTMs that, at the same time, improve their interpolation, the differential rectification of the image, and the fitting of the vectorial information on the model.
It is axiomatic that in digital modelling the whole system run with the best approximations guaranteed by the vectorial and punctual information derived by stereorestitution with precision instruments such as Planicomp, and adjusting the interpolation so as to avoid qualitative jumps among homogeneous information.
The principal objective of this part of the project is the set up of a methodology for the acquisition of data that are integrated with the buildup of the stereomodel for tridimensional modelling of images producing, as value added, layers of vectorial data that are geographic, synthetic, significant, very precise, and in cartographic projection.
These layers constitute the vectorial framework of the land, carrying information of varying details according to the method of the survey: thalweg and banks of rivers, elevation points, DTM, also given by contour lines, toponimy, administrative borders, the coastline.
Already in this form the land is all divided in polygons, delineated by the administrative borders that contain the relational coding to the administrative information, population, income, activity etc.) and further subdivided by the surface hydrography. The subdivision of the administrative limits contains the polygonal cadastral subdivisions in maps that document the polygons of the cadastral tracts codified in relation to the fiscal data such as ownership, agricultural production etc... The administrative limits with the geographical data described constitute the planimetry of a first layer that is general and complete.
If we connect the watershed lines with the river channels, and we trace the contours of drainage basins, we obtain a further subdivision that greatly simplifies, with high precision, the parcelling of montaneous land by valley sides to which we can tag automatically and accurately values of slope and exposure.
This activity is carried out on the vectorial skeleton overlain to the orthophotomap guaranteeing maintainance of congruency among the data. With the same method or with stereorestitution we can add roadways and buildings having the characteristics requested by the user. The type of information detail and its accuracy are not necessarily homologous; the criteria with which they are inserted or not in the geographic data base derives from their origin, their synchronousness, and their congruency with

the geometric characteristic of the "zero" base data. But this does not impair their use as a layer temporally or geometrically discordant.

It is contemplated to test the congruity of photointerpretation with the integration of direct surveys concerning for example, stream sources. The need of unequivocal localization of features such as springs, forces as to revalue field surveys (reconaissance) today generally neglected.

These data represent the web into which time slips and curls.

Every bit of data brings with itself its temporal coordinate so that, for example, an update may be effected via XYZ or via t, as a place change or as time that has brought changes.

The use of orthophographic images permits updating quickly and cheaply; moreover the use of remote sensing techniques or of image treatment have in the orthophotomap the principal instrument to make data geographic.

For the historical anaysis of the landscape, the remote shadows of the past can still be seen on the orthophoto.

Those signs nurture the disciplines of ancient topography, history, geography and natural science, to make geographic the documentation of the history of the land that resides in the archives, and make it thus usable by the system. Even the use of oblique photos may be of great help to document the past in that, once you have reconstructed the prospective and recognized known points, their information content can be tied in space and georeferenced. In other cases the analysis of documents and their referencing to the "zero" situation will go through their localization on the cartography of the times. This, if with even greater and more different problems than with oblique photos, will find an adjustment on the "zero" situation with techniques of image processing, save for a correct attribution that can be obtained from photointerpretation and field examination.

This reconstruction of the past is indispensable for modelling.

The historical data are in fact necessary in all empirical models to determine the parameters and the constants, for calibration, and to evaluate the models' reliability.

To exemplify the general concept it is useful to describe a particular application recently completed in Italy concerning the problem of forest fires. I refer to the "Feasibility project of a forest information system and fire risk map" conducted jointly by ITALECO S.p.A. (IRI-ITALSTAT group) and the Compagnie Generale Ripreseaeree that is the main part of the Consorzio Compagnie Aeronautiche of Parma (14).

The complex mechanism of the hourly, daily, monthly, and seasonal indeces was tested on the forest fires that actually occurred in the last 10 years, opportunely distribuited in space and dated and correlated to the local microclimate.

In the same way there is a need to verify, for example, the sedimentation or erosion that coastal or fluvial structures can create, the hydrologic balance of a basin undergoing reforestation, the impact of tourists' activities vis a vis a new road, the impact of the EEC politics on the agricultural market. This would determine a use of the information system with a high value added and its characterization as a principal instrument of support to decision making.

The state of the art, particularly for the project EU516 ENVINET GEOKRONOS suggests and perhaps mandates the use of a host or mainframe hardware and, perhaps, dedicated processors but a great many parts of the proiect have immediate applicability and are run and tested on work stations (15) with a logic that is not only precompetitive but also capable of accomplishments that are not prototypes but operational. Particular attention, in this respect, is dedicated to image correlation, not only as it

14 - The project belongs to the Ministry of Agriculture and Forests (Ministero dell'Agricoltura e Foreste, Direzione dell'Economia Montana e Foreste).

15 - IBM, Silycon Graphics.

concerns the construction of DEM, but also for expert system and object recognition (presence, absence, typology), and also for the support of aircraft carried microwave, radar and scanning sensors.
The integration with data from satellites, further, is another aspect of the project, in particular as it concerns meterological and oceanographic geostationary sensors or those with a greater frequency of passage, which are, even in their limited resolution, extremely useful to circumscribe events not otherwise space referrable withouth a dense control network on the ground, hardly emplaceable in a short time and, in any event, not available for the past.

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ABSTRACT

To insert time as a fourth coordinate in environmental Geographic Information Systems (GIS) seems indispensable to affirm their support role in knowledge acquisition and in decision making.
Aerophotogrammetry provides an important role both in the attribution of time coordinates to environmental events and in the attribution of geographic coordinates to events documented by means other than photogrammetric.
The use of orthophotography, and its computerized development and management, appears to be particularly useful for the documentation, management and representation of the environment in the framework of the laws of thermodynamics and of the interdisciplinarity of Landscape Ecology.
In this light we analyze agreements and functions of existing cartographic forms,on the basis of their history and the needs of environmental GIS, describing, briefly, ongoing applications.

Dr. A . Castagnoli
Consorzio Compagnie Aeronautiche s.r.l.
Via G. Rossi, n. 5
43100 PARMA