ON AN INTERACTIVE SYSTEM TO SUPPORT THE MANAGEMENT OF INDUSTRIAL RUBBER TREE (HEVEA) PLANTATIONS

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ABSTRACT

The use of remote sensing and Geographic Information System (GIS) for the needs of industrial plantations management, has occupied more and more important place during the last years. In the case of the hevea culture, this can be explained by the need expressed by agronomists to achieve development, inventory, maintenance and farming operations, on the plantations, by means of aerial images, topograph- and descriptive data. Most of these operations integrate decisional procedures using models from Statistics, Operational Research and Artificial Intelligence. The DSS presented here has been designed in this context. Its main particularity rest on the fact that most of the decisional procedures implemented need a simultaneous use of the three types of data cited above. Our approach uses a modelization of the user's conceptual space in the shape of a state graph. A session in the system may be viewed as a partial exploration of that graph. The control of this exploraton is completly left to the user. Furthermore the system provides the user with a set of operators allowing him to generate new states from the current one, and a set of functions based on some decisional models for the evaluation of the generated states.

Keywords: DSS, GIS, Remote Sensing, heuristic search

INTRODUCTION

The management of industrial plantations of hevea involves (among other things) the operations of installation of sites, inventory, maintenance and exploitation. An hectare (100 m^2) of hevea planted, counts in average 550 plants. Consequently, a modest plantation of 5000 hectares would contain about 2 500 000 plants. Note that the life time of a plant of hevea is about 35 years. During this period, the heveaculture practitioner regularly supervises its growth and its phytopathological conditions. These conditions are often watched througout the textural analysis of the leaves. Besides, the hevea plantations are organized in blocks which are disposed according to a matricial configuration. Each block is then marked out in band-line and in band-column to the intersection of which it is located. On the same principle, a block is organized in lines and in columns whose intersections point out potential plantable positions. Adjacent blocks having the same type of hevea (clone), the same cultivation year and the same mode of planting, are grouped in plots according to some precise criteria. Moreover, in order to organize the harvesting of latex in a plantation, adjacent plots are grouped in plates according also to some precise criteria. This description of the field of an industrial plantation of hevea points out some essential features of the information system; that are:

1) the important volume of informations induced by the necessity to supervise individually each plant in a block;
2) the importance of the covered area (in Gabon for instance, a plantation of hevea covers in average 1 000 ha);
3) the diversity of georeferenced objects (structuring elements of the plantation) which present a particular interest for the heveaculture practitioner's point of view ;
4) the importance of topographic or textural informations in the management process of industrial hevea plantations.

The practitioner of heveaculture uses all these informations in order to take decision about:
- the maintenance and the exploitation of spaces;
- the nature and the mode of phytopathological treatments to apply individually to each plant in a given block;
- an optimal affectation of human or material resources;
- the opportunity to tep in the plots.

In order to meet these requirements, the D.S.S (named HEVEASCOPE) that is presented here, uses an information system including numeric images, descriptive and topographic data, in order to implement decisional procedures based on Statistic, Operational Research and Artificial Intelligence models. Most of the decisional procedures implemented, need a simultaneous use of the three types of data cited above. Our approach uses a modelization of the user's conceptual space in form of a state graph. A session in the system may be viewed as a partial exploration of the state graph. The control of this exploration is completly left to the user. Furthermore, the system provides the user with a set of operators allowing him to generate new states from the current one, and a set of functions based on some decisional models for the valuation of the generated states.

This paper is organized as follows :

In section I) we present the data base of the system;
section II.) introduces an example of decisional model implemented;
in section III.) we present the way the user's conceptual space has been modelized;
in section IV.) we present the interface.

I°) DATA BASE OF THE SYSTEM

I.1°) The nature of the data

The data generally used in GIS applications are in two types [DIDO, 92] :

a.) (Geo)graphic data : they are topographic data and image data.

a.1) Topographic data are organized in information plans; the following information plans have been integrated in our system :
- blocks, plots and plateaus which are the structuring elements used by farmers in their agricultural undertakings;
- garden which are production areas grafts and seedings used in setting, maintening or developping blocks;

- villages which are living areas for plantations workers. Moreover our system will take into account in subsequent version, the program of villagers rubber tree plantations;
- roads and hydrographic networks.

a.2) Image data are organized in pixel matrixes. These are usually aerial photographic pictures. Satellite pictures can also be used. Image data are important in the survey of the phytopathological and growth condition of rubber trees. Collating image data upon topographic data necessitates preliminary processing such as texture analysis and classifying [REVI 92]

b.) Descriptive data

Each geographic object of the GIS is linked to a set of descriptive informations. In our system, they are organized following the relational model [ADIB 82][GARD 83]. Most of these descriptive data have no intrinsic space location, as in the example of material and human resources: their association with a geagraphic object depends on either they are in storage or in use.

contrary to the approach of many GIS, association of geographic objects and descriptive informations follows a dynamic line. Here is succintly presented the matching system to this effect.

I.2°) Associative relationship of descriptive and (geo)graphic data

Flexibility in structuring descriptive data has become possible through disjunction in the designing process of descriptive and (geo)graphic data. To make possible the integration of the two types of data, we have to describe the possibilities of association existing between the information plans forming the (geo)graphic model and the relationships constituting the descriptive model.

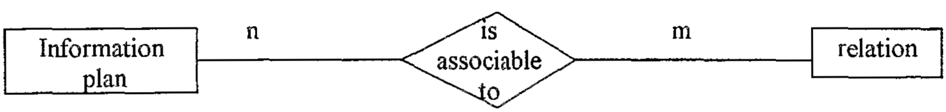


figure 1 : conceptual scheme of associative relationship between descriptive and (geo)graphic data

The matching system allows the effective association (in a dynamic way) of information from the descriptive data base and information plans. Such an association must take into account the current context. The matching system makes use of the following ressources:
- The association table presented above;
- a base of contextual queries composed of a set of triplets of the form

([<operation>], <information plan>, <query>])

in which <operation> (optional) represents an operation in progress and <query> is a query allowing to create the table that will be actually associated with the information plans.

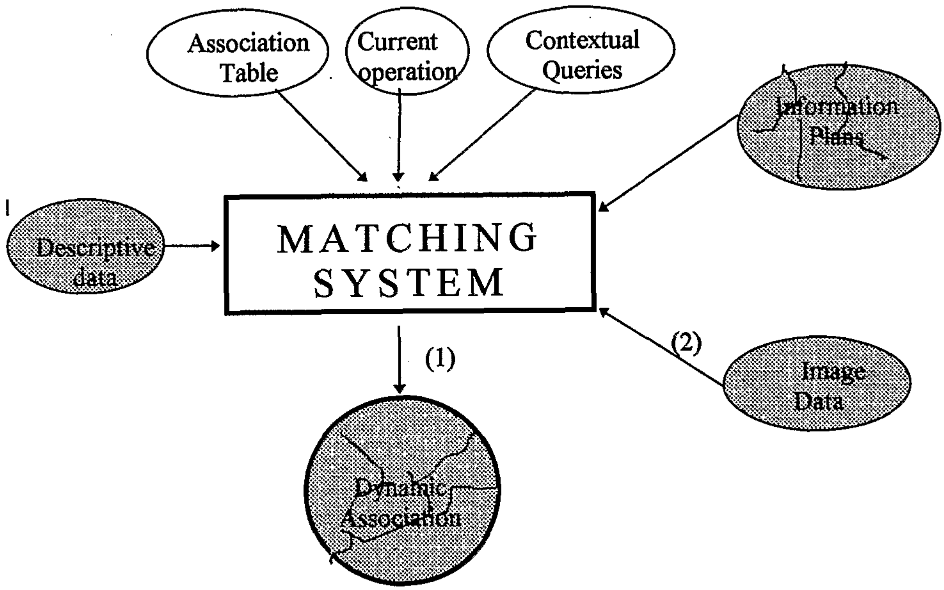


figure : Dynamic association system

(1) synthesis or joint
(2) image analysis followed by update of georeferenced data (data with spatial attributes)

II.) AN EXAMPLE OF DECISIONAL MODEL IMPLEMENTED

In order to emphasize the main particularity of this DSS, we present here, one of the implemented decisional models. This one is dedicated to provide aid for spatial organization of blocks in plots, in plates or in clones under some precise criteria. In order to perfom this task, the heveaculture practitioner may carry out a multidimensional analysis. The data used are generally in the shape of a matrix X(n,p) in which objects «blocks» are on line position and variables (observable parameters) are on column position. The relevant parameters for this analysis are for instance, the area, the growth state, the yield, the quantity of fertilizer used, the spatial position, and the health state of blocks. The large number of observable parameters used in the spatial structuration of plots, plates and clones, does not authorize the practitioner to rapidly assimilate the information contained in the matrix. Note that there exists two families of methods used to realize this assimilation; namely :

- Factorial methods which provide graphic representations on which the geometric proximity between line-points express statistic association between lines and between columns.
- Classification methods which provide classes (or families of hierarchical classes) of objects.

These two families of methods could be used in a complementary manner to demonstrate the proximity between blocks as from those noted between observable parameters. This must lead to a satisfactory spatial organization of plots. The choice of the method to be used is closely linked to the nature of the data. The rules of interpretation of the obtained graphics don't have the same simplicity as the elementary descriptive statistics. The interpretation of histogramms, for example, is intuitive while in the case of correspondance analysis, it is necessary to identify the interpretation rules. This is a difficult task in spite of the suggestive character of the representation obtained. The working scheme of the decisional model in the spatial organization of blocks may be described by the following sketch :

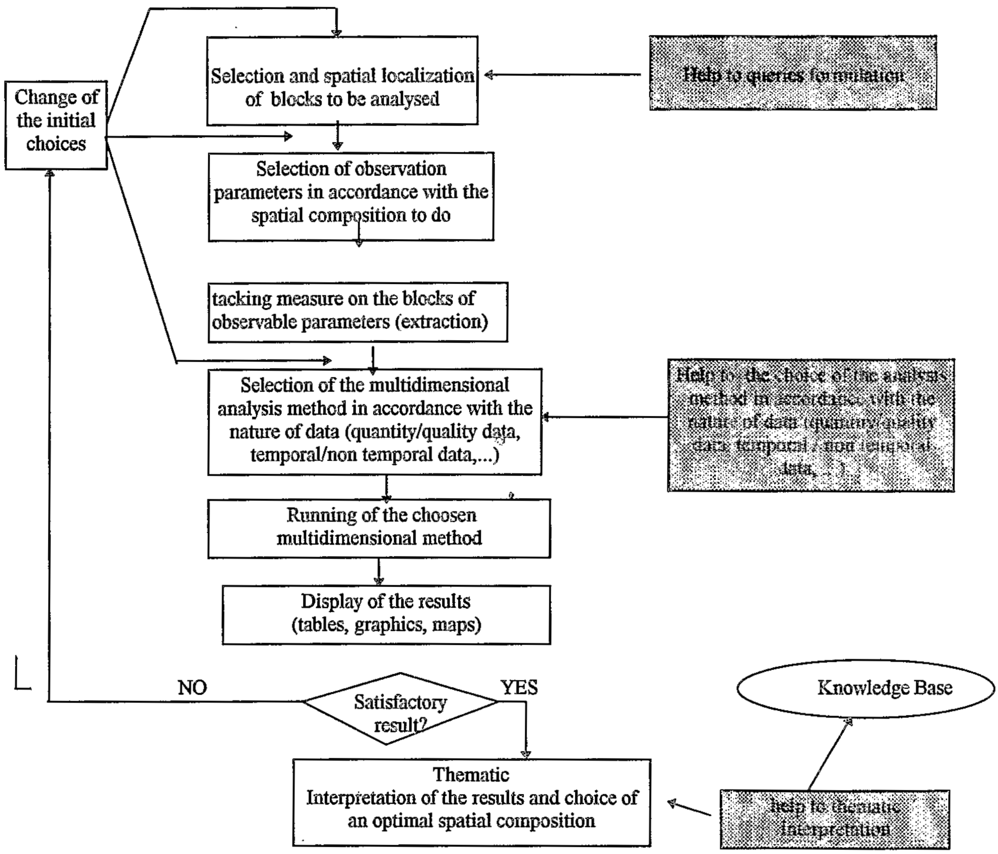


figure 3: working scheme of the decisional model used for the spatial organization of blocks

III) MODELIZATION OF THE USER'S CONCEPTUAL SPACE

In addition to the management of the information system, our system provides the user with a set of decisional models that can be used for analysing the state of the plantation or that of the yield. The working philosophy of this module is that the aim of the analysis must be completely open and left to the user's judgement[COUB 87]. It's based on the modelization of the user's conceptual space in form of a state graph and on the definition of support tools for the exploration on this graph. The nodes of this graph are the representations of the plantation materialized each one by a map.

The system provides the user with a set of functions for the valuation of each state in accordance with his target and a set of operators allowing him to generate new states from the current one. A link between the nodes S1 and S2 corresponds to the existence of an operator O such that O(S1) = S2. The initiative for the valuation of a state or for the generation of a new state is completely left to the user.

II.1°) Description of a state

A state in the user's conceptual space is a map composed of information plans taken in the following set of basic plans:

C = { block, plot, plate, clone, garden, village, contour }

The initial state on which the system starts may be represented by:

Eo = [block, plot, plate, clone,road, contour]

This writing denotes the map that is composed of the information plans ' block', 'plot', 'plate', 'clone', 'road', 'contour' as well as the tables relating to these informations plans.

In the list of the plans that compose a card, one distinguishes a particular plan viewed as the active plan and on which decisional models (state valuation functions) are applied. The other information plans are mainly useful for the display.

III.2°). Evaluation of a state

The user can perform three kinds of valuation on a state :

1) A visual valuation (completely abstract and subjective) resulting in feelings or ideas the displayed map inspires him.

2) Quantitative and numerical evaluation which consists in applying on the current state E, one of the decisional models (issued from statistical and operational research models). The working scheme of one of these models is presented in figure 3 above.

3) A symbolic evaluation (expert system) which consists in applying on the current state, an expert system performing backward chain inferences on a user's goal.

This module can, for instance, be used during the creation of a block in order to specify its limits by taking into account some pedologic or climatic knowledge or the history of surrounding blocks.

III.3°). Change of a state

The present DSS has been designed in order to allow the engineer to investigate a situation in a non imperative way. Thus after having performed some valuation on the current state, he can choose to analyse a new state (that he finds) more promising.

The state change operators provided are :

- <u>Selection</u> which allows to generate a new state by selecting in the current state, objects that meet a given criteria ;
- <u>Union</u> which generates a new state by bringing together objects appearing in two states which are already processed;

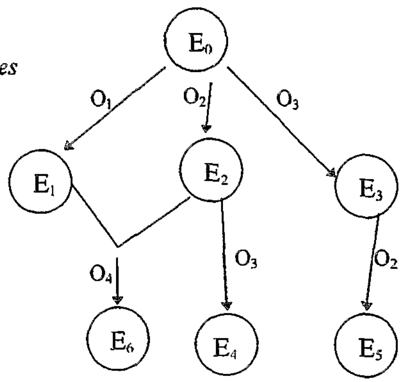
- Intersection which allows to generate a new state by performing the intersection of objects that appear in two processed states;
- Symmetrical difference of two states;
- Integration of new information plans;

III.4°) Management of the state space

The state space is potentially infinite as in most problems of research in a states graph [LAUR 88]. In order to make the synthesis of a work session and, if necessary, to give the trace of the steps which have lead to the generation of the current state, the system manages a description of the generated states.

Suppose that, at a given instant, the set of generated states be described as follows :

figure 4 : generated states



This figure expresses the fact that from Eo, the user has generated the following states:

$E_1 = O_1(E_0)$	$E_2 = O_2(E_0)$	$E_3 = O_3(E_0)$
$E_4 = O_3(E_2)$	$E_5 = O_2(E_3)$	$E_6 = O_4(E_1, E_2)$

The system will preserve the list of states which are on the path from E_0 to the current state E_6. This path may be denoted by $[E_0, (E_1, E_2), E_6]$. The system also preserves the sequence of operators which has allowed to pass to E6 from Eo namely $[(O_1, O_2), O_4]$.

Moreover, each processed state will be represented by an identifier, the operator which has allowed to generate it and the states from which it has been generated. Then, for the states E_1, E_2, E_6, the representation will be :

(E_1, O_1, E_2)
(E_2, O_2, E_0)
$(E_6, O_4, (E_1, E_2))$

These informations are sufficient to redraw the part of the states graph already explored. Then, each state already explored may be reconstituted in order to serve as the initial state of a new development. On the other hand, a working session may be simulated from the saved sequences.

IV°) THE SYSTEM'S INTERFACE

One of the main features of a DSS is its interactive character[LEVI 90] [ANDR 83] [COUB 87]. This one is associated (and almost identified) to the notion of control in a process of heuristic research[.LAUR 88.]. Several authors stress the fact that in a DSS all, or a part, of the control of the states space exploration is left to the user.

According to this philosophy, the interface that we propose offers three essential functionalities to the user namely :

- the displaying of the current state of the system;
- an help to the user while running a decisional procedure on the current state;
- the generation of a new state;

IV.1°) Displaying the current state

As it has been noted in the previous paragraph, georeferenced data take up a privileged position in the architecture of the information system. Each state of the system is built from a set of georeferenced to which is associated the result of image analysis or the synthesis of information from the relational data base (descriptive data). The displayed map constitutes a user friendly representation of the current state as in the following map which represents a state constituted of a grouping of plots

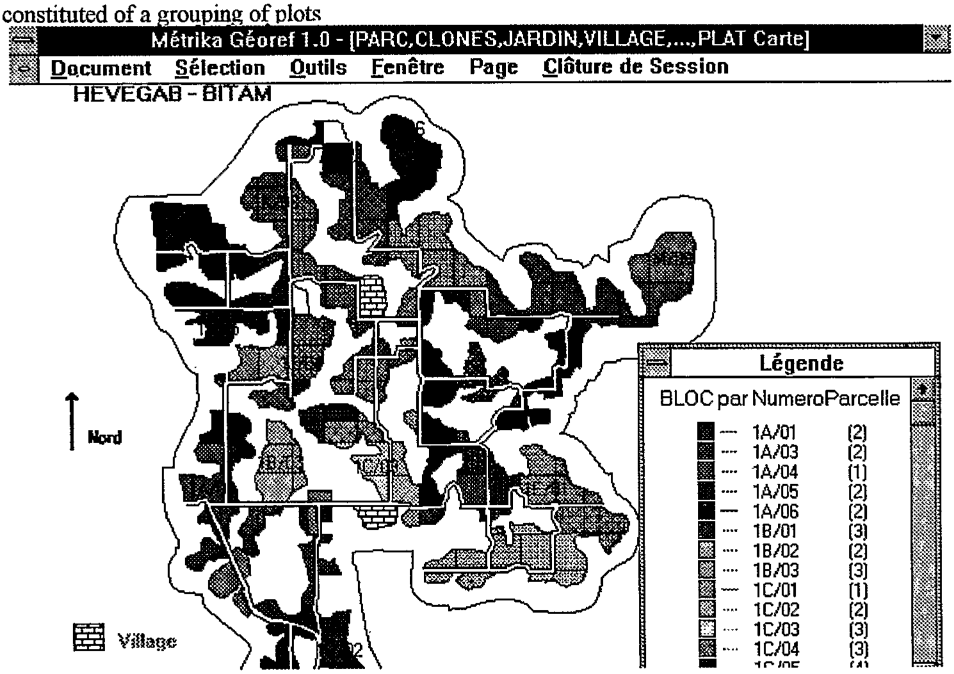


figure 5 : Representation of a state by a map of plots

IV.2°) Support to the execution of decisional procedures

The interface of the system provides a menu with different statements allowing to start the execution of decisional procedures. Some of these statements use additional data coming from the relational data base. An assistance in writing the queries is proposed to the user in this case.

The result of th execution of decisional procedures are given in the shape of graphic in the form of cipher information displayed in a form.

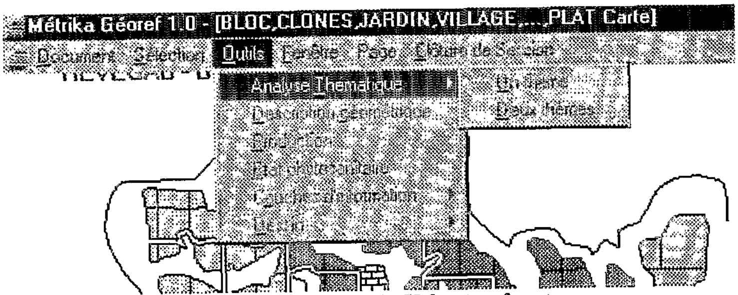


figure 5 : Valuation functions

IV.3°) Generation of a new state

The generation of a new state is done by the means of set and logical operators that are applied to the current state or to a state previously generated. The user has an access to these opeartors through a menu in which statements carry into effect operators of state construction.

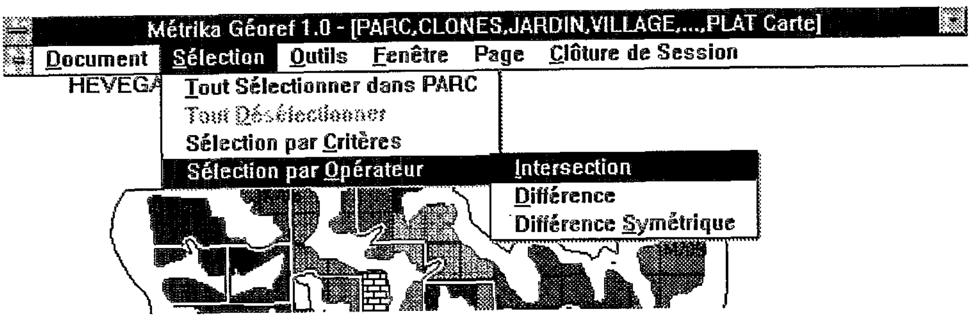


figure 7 : Operators used for the generation of a new state

CONCLUSION

The system presented here uses the most recent concepts and developments of DSS to assist the heveaculture practitioner in the management of an industrial plantation. Its main features are:

- the use of structurally different decisional models from Operational Research, Statistics and Artificial Intelligence;
- the modelization of the user's conceptual space in the shape of a state graph. This guarantees to the system its interactive character;

- the use of a user-friendly GIS interface;
- the use of decisional models with varied data sources.

This system is effectively used by engineers in industrial hevea plantations in Gabon. Its utilization in industrial hevea plantation in Cameroun and Côte d'Ivoire is envisaged in the short term.

An interface adapted to the use by high level decision makers based on the notion of sub-language[KITT 89] is in study.

REFERENCES

[ADIB, 82] M. Adiba, C. Delobel : Bases de données et systèmes relationnels - Dunod 1982

[ANDR, 83] S.J. ANDRIOLE: Interactive computer based system: design, implementation and evaluation, North Holland, Amsterdam, 1983

[BOSM, 83] A BOSMAN: Decision support system, problem processing and coordination, in sol, 1983 pp 79-92

[CHAT, 92] M. CHATAIN.: Télédétection et Système d'informations géographiques appliqués aux études d'environnement, Document pédagogique, GDTA sept 1992

[COUR, 83] J.C. COURBON: Les SIAD; outils, concepts et modes d'action AFCET, interface 9 pp 30-36, 1983

[COUB, 87] J.C. COURBON: L'interactivité dans un SIAD: illustration de quelques idées à partir d'un prototype de système d'ordonnancement d'atelier Séminaire informatique et décision université Pierre et marie Curie 1987

[DIDO, 92] E. DIDON : Système d'information géographique. Document technique GDTA, sept 1992

[FORT, 91] J.P. Fortin, M. Bernier : Transformation de données acquises par télédétection en données utiles pour le modèle hydraulique Hydrotel - dans Télédetection et gestion de ressources - 7ème congrès de l'association québécoise de télédétection, 1991

[GARD,83] G. Gardarin: Bases de Données. Les systèmes et leurs langages Eyrolles, 1983

[HAIN, 90] R.P. HAINING: Spatial data analysis in the social and environnemental sciences, Cambridge university press oct 1990

[KITT, 89] R. KITTREDGE The significance of sublanguage for automatic translation In Machine learning Ed. Sergei Nirensburg, Studies in natural language processing,march 1989

[KOUS, 95] S. KOUSSOUBE, J.L. NDOUTOUME, R. NOUSSI: sur une architecture fonctionnelled'ungénérateur d'applications SIG orientées analyse et modelisation. Publication Interne IAI, janvier 1996

[LAUR, 88] J.L. LAURIERE: Intelligence Artificielle, résolution de problèmes par l'homme et la machine. Tome 1 Eyrolles, 1988

[LEVI, 90] P. LEVINE, J. C. POMEROL: Systèmes Interactifs d'Aide à la Décision et systèmes experts. Edition Hermès, 1990

[REVI, 92] P. Y. REVILLON: Apport de l'imagerie de télédétection aux systèmes d'informations géographiques. Document technique GDTA sept 1992

[THIR, 92] S. THIRION: Matériels et logiciels dédiés aux SIG et au traitement d'image, Document technique GDTA, sept 1992