

A DECISION SUPPORT SYSTEM FOR WATER RESOURCE MANAGEMENT IN LIFOU ISLAND, NEW-CALEDONIA

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Abstract

ADAGE¹ is an innovate program for decision support in environmental development and management developed since 1996. Based on the fact that the scientific expertise does not have a vocation to give the answers to the problems posed by the decision maker, representing the civil society, ADAGE was developed on the idea of implementing data and expertise in the field of decision-making and integrated into the responsibility domain in an understandable and usable new tool. ADAGE makes the interface between the domain of observatories - studies and scientific actions that allow the knowledge to emerge of the phenomena - and the domain of the political strategy, political power and social pressure. These two domains have their indicators, their concepts, their culture and their behaviour, origin of misunderstanding and conflicts.

Developed as prototype in three regions (French Guyana, Portugal, Western France) about three environmental problems (Water quality, Waste management, Water rehabilitation of a harbour), this original approach was developed in New Caledonia (south-western Pacific) in 1999 for a sustainable management of the water aquifer of Lifou Island. This paper proposes to explicit this project by the way of the description of one of the products: the Decision-Support System. This tool uses or simulates various kind of knowledge, from the SPOT satellite data to real-time watch-over of the resource, from the social and cultural behaviour and reactions of the population to the politics' indicators, while using artificial intelligence technologies.

¹ ADAGE Concept : FRANÇOIS Nadine (ALCATEL), HUYNH Frédéric (IRD), LILLE Didier (IRD), NOËL Jacques (IRD), POLIDORI Laurent (IGN).

Introduction

An European consortium with complementary skills: IRD (France, ex ORSTOM), ALCATEL Space Industries (France), EID (Portugal) and the Common Centre of Research of the European Commission (Italy) have been developing since 1996, an innovative project for decision support in environmental development and management (*ADAGE: Aide à la Décision en Aménagement et Gestion de l'Environnement*).

The ADAGE concept is based on the fact that the scientific expertise does not have a vocation to give the answers to the problems posed by the decision maker, representing the civil society. ADAGE does not replace the analytical processes and observation and even more the decision process, but presents itself as an approach for communication and negotiation, where each domain has its role to play.

For the originality of the approach, ADAGE has obtained the European EUREKA label (EU1299) in 1996¹.

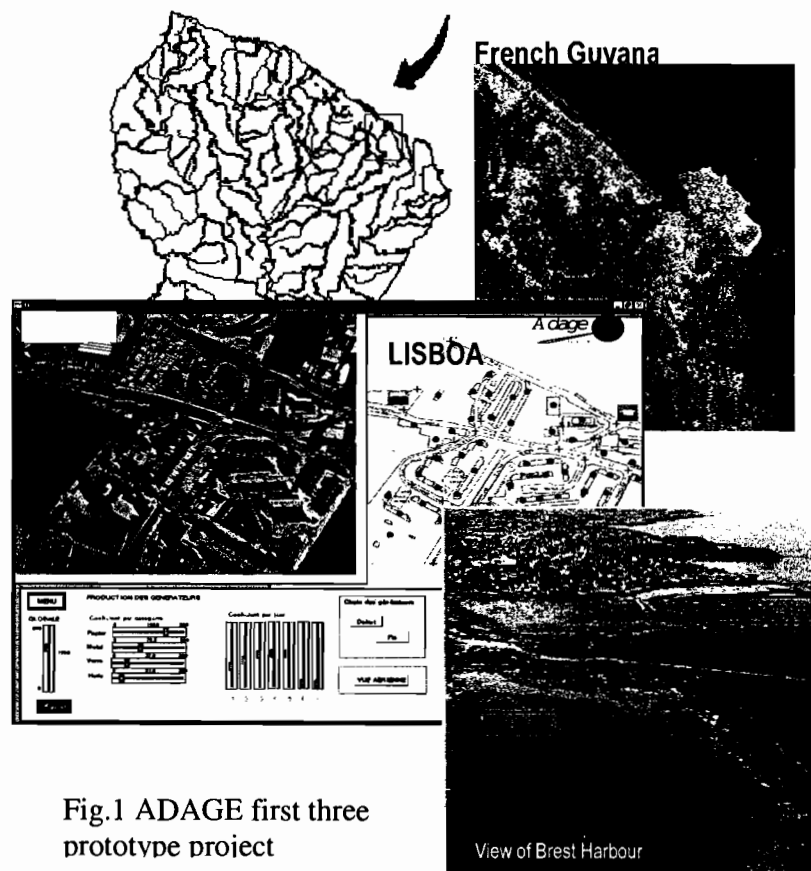


Fig.1 ADAGE first three prototype project

Three environmental problems were kept for the development of prototypes: the rehabilitation of the quality of the water of a harbour² (Brest, France), the collect, management and elimination of selective wastes in a context of urban development³ (Lisbon, Portugal), and the management of used water and rainwater in an urban area facing draining problems⁴ (Cayenne, French Guyana).

The existence of this interface allows the mutual comprehension of the objectives and processes of each party (the decision-makers and the political managers of a human, scientific and technical society, in charge of the corporation of knowledge mastery). Furthermore, this putting together of concepts and indicators is the necessary basis for a simulation of the impact and consequences of the decision, accepted by each of them. The ADAGE filter constructs a consensus of a solution, presented on the one and other hand with accepted and known concepts: the social dimension of the problem is taken into consideration.

^{1 2 3} Head of project : Nadine François (ALCATEL), Jacques Noël (IRD)

⁴ Head of project : Frédéric Huynh (IRD)

This approach was, for the first time, developed in the South Pacific in 1999, for sustainable management of the fragile water resource of LIFOU Island⁵, in New-Caledonia. Since the set up of the prototype, developed in above quoted regions, the tool, called Demonstrator, has been strongly and deeply improved (D. Lille) noticeably with the integration and spatialization of social, cultural and environmental data collected and analysed through an original approach based on cultural geography (C. Jost).

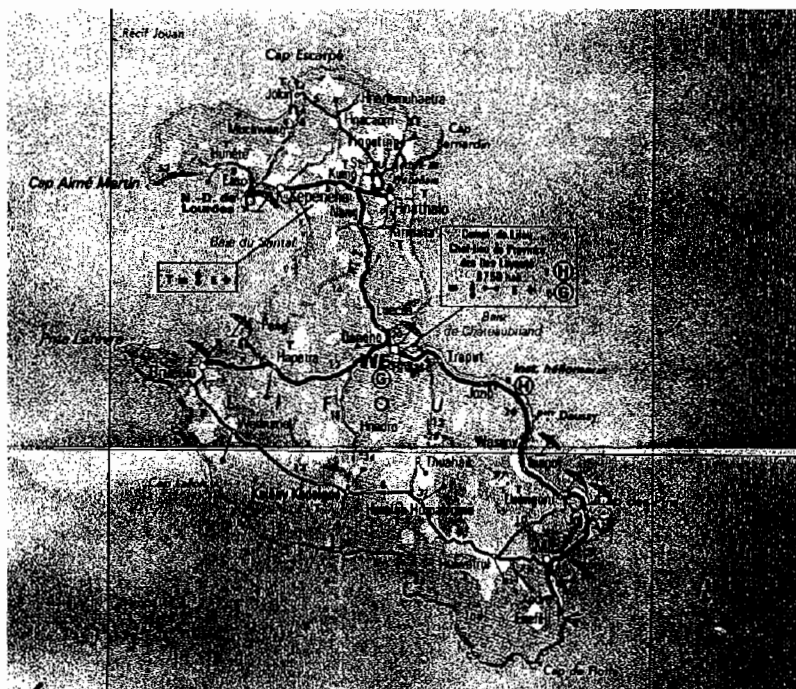


Fig.2 Lifou Island – Loyalty Islands - New Caledonia

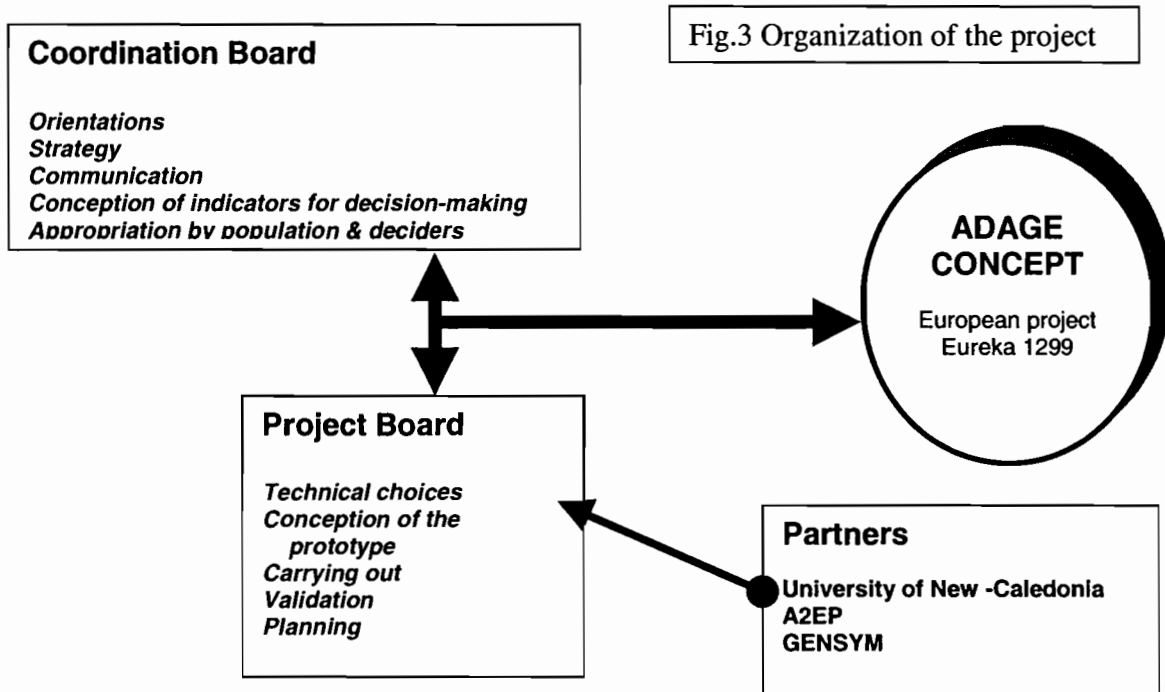
This paper proposes to explicit this project with the description of one of its products: the Decision-Support System. This tool uses or activates multidisciplinary knowledge and processed figures, from the SPOT satellite data to real-time watch-over of the resource, from the social behaviour and reactions of the population to the politics' indicators, while using artificial intelligence technologies. **Why a Project for sustainable management of ground water of LIFOU island ?**

Because of a lack of surface drainage on this uplifted calcareous atoll, the ground water of Lifou island is the unique source of drinkable water. Extended on 119,600 hectares the island is homing 9,614 permanent residents and has a density of 8.2inhab/km². A dynamic demography and the numerous projects of development have absolutely to be confronted with a coherent management of this resource. Major actress of the island's ecosystem, the water lens undergoes numerous aggressions related to human activities whose impacts, today, are still not disastrous, mainly due to the weak density of the population (8.2inhab/km²). Moreover, the continuation of present behaviour and bad habits regarding water consumption, added to the increasing demographic pressure and a legitimate economical development, are contributing to endanger the resource with time. Therefore, factors of present and future aggressions require to be identified and analysed. The actions to start up

⁵ Head of project : Didier Lille (IRD)

with must be specified and a management tool for the ground water needs to be set up. It appears a necessity to elaborate a concerted strategy for the management of this soft water resource, first to master and anticipate consequences of the human activity on the future of the ground water, second to use and allow an optimal evolution of the water conveyance network.

Organization of the project



In order to help orienting the project, a **Coordination Board** was set up gathering:

- La Province des Iles
- The Lifou council
- Custom Authorities
- The ADAGE group

Moreover a **Project Board** was organised in 11 work units to allow an optimisation of the work and constant exchanges between disciplines and thematic through « facilitators ». A particular attention was given to the **communication** part of the project for it to be efficient either between thematic research groups than between the scientific community and the institutions. The diffusion of information within the population and the tribes was organised through the customary authorities. All existing formal or informal circuit of communication were and are still used (schools, women rights association, men of God, customary chiefs,...)

Data in the decision-making process

The task of inventorying and analysing the environmental data allows to guarantee that the available data will provide relevant and useable information for the decision-making process. It plays then a role of filter between:

- Upstream: the collect of existing data and the creation of new data
- Downstream : in the integration of data into the tools to help decision-making (dashboard, impact simulator, communication support system..)

Environmental data about Lifou have only been partly collected and gathered in accordance to the aim of the project. This is the case of the studies conducted by the “Social sciences and Environment Unit²”, which released and spatialized new data on population perception and behaviour, on the risks and threats to the water, and on population and economic development statistics. All the other information have not been created on purpose according to the problematic, but were formerly elaborated either with no specific commendation or for management purpose not necessarily linked to a ground water study. Therefore it was predictable that not all data were adapted to the studied problem and this for various reasons:

- Heterogeneity of data: digital accuracy, thresholds, non comprehensive data, incompatible support, reading format, repetitiveness’, data file settings,
- Lack of description inp data attributes: non specified units, meaning or non coherence of attributes, of codes, lack or ambiguous parameters,
- Non adequation between data and aims: level of image processing, projection systems, scale, data accuracy,
- Non accessibility of data: non available, loss, confidentiality, prohibitive cost, unknown location of data,

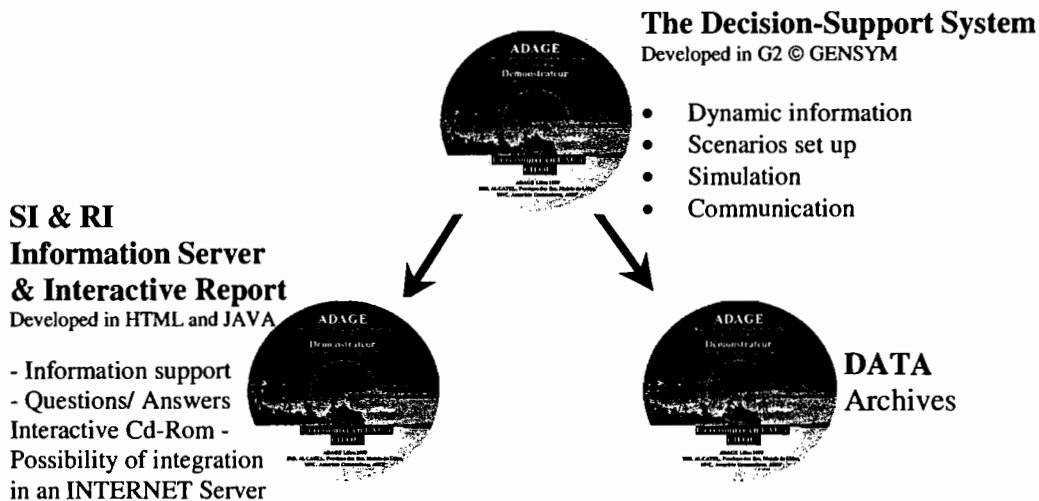


Fig. 4 Organisation of the computed products

² Dr Christian Jost, Head of the “Social sciences and Environment Unit”

Description of the Demonstrator

- Developed in G2 © GENSYM language
- Cartographic basis GIS georeferenced
- Data basis object oriented and related to water
- Temporal simulations
- Running of the peripheral systems
- Orientation according to real time

The first problem, quite usual, which came out, was the heterogeneity of data and systems sources, especially among the GIS, the data base management systems and the processing image systems. The solution that was chosen was to try not to modify any organization, but to establish dynamic links between the central system and the systems providing data. This way an independence and a development of the whole procedure is guaranteed. The aim is here to put at disposal an existing yet dispersed (therefore hardly usable) information and not to try to organize it in a centralized way. This integration processes has been developed generically and will be usable via Internet.

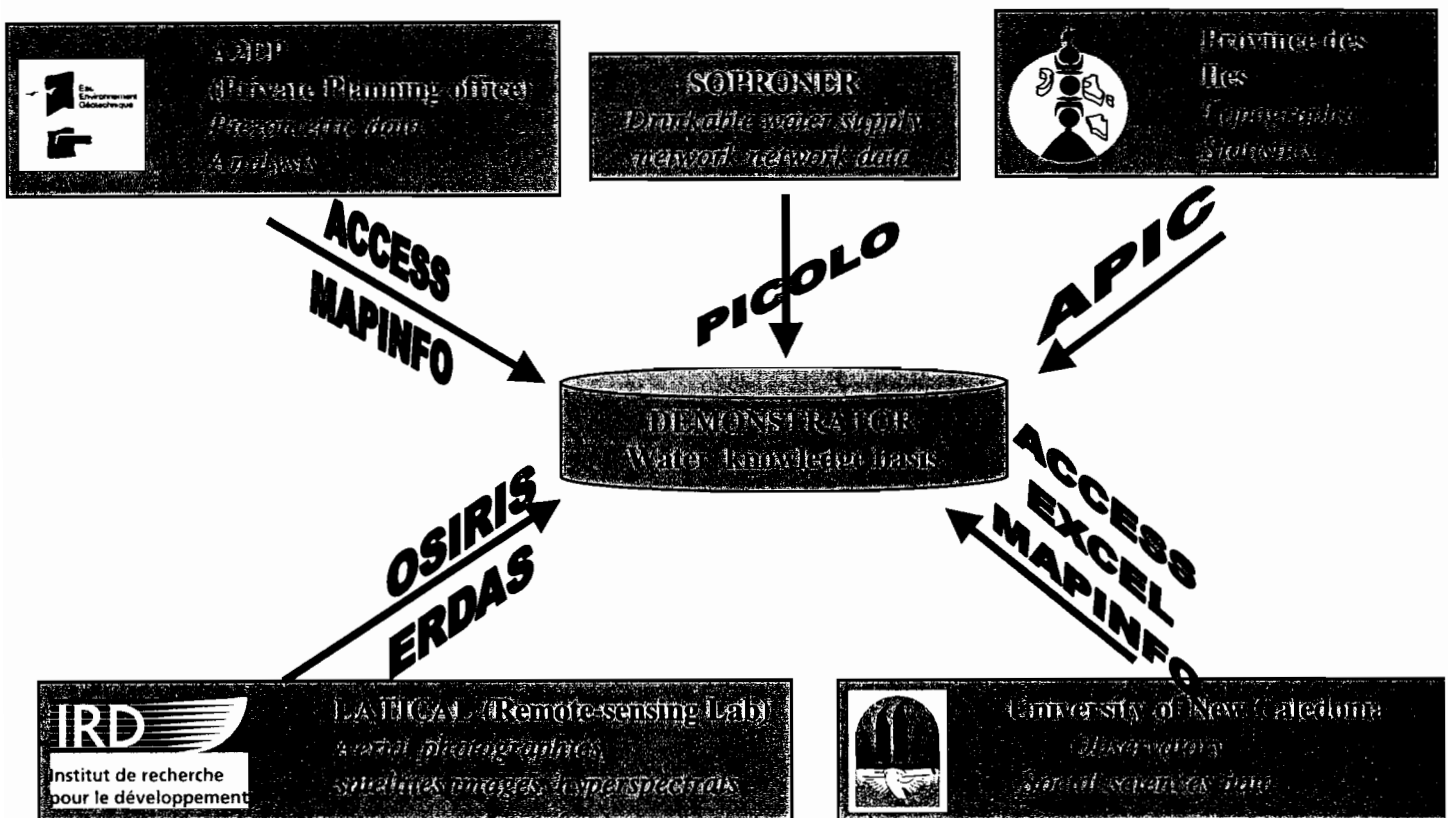


Fig.6 Partners and their contribution

Description and use of the demonstrator tool – The global interface

A tool of dialogue and of communication involving multi-actors dealing with :

- interactions :
 - water and demographic evolution
 - water and tourism development
- risks and threats for the ground water related to agricultural activities (fertilisers, pesticides, irrigation,..)
- risks for the ground water in respect to cattle breeding and other polluting activities
- impact of unauthorised waste dumps
- optimisation of the use of drillings and of the water conveyance network
- environmental legislation
- appropriation of the project by the population
- support given to decision-makers

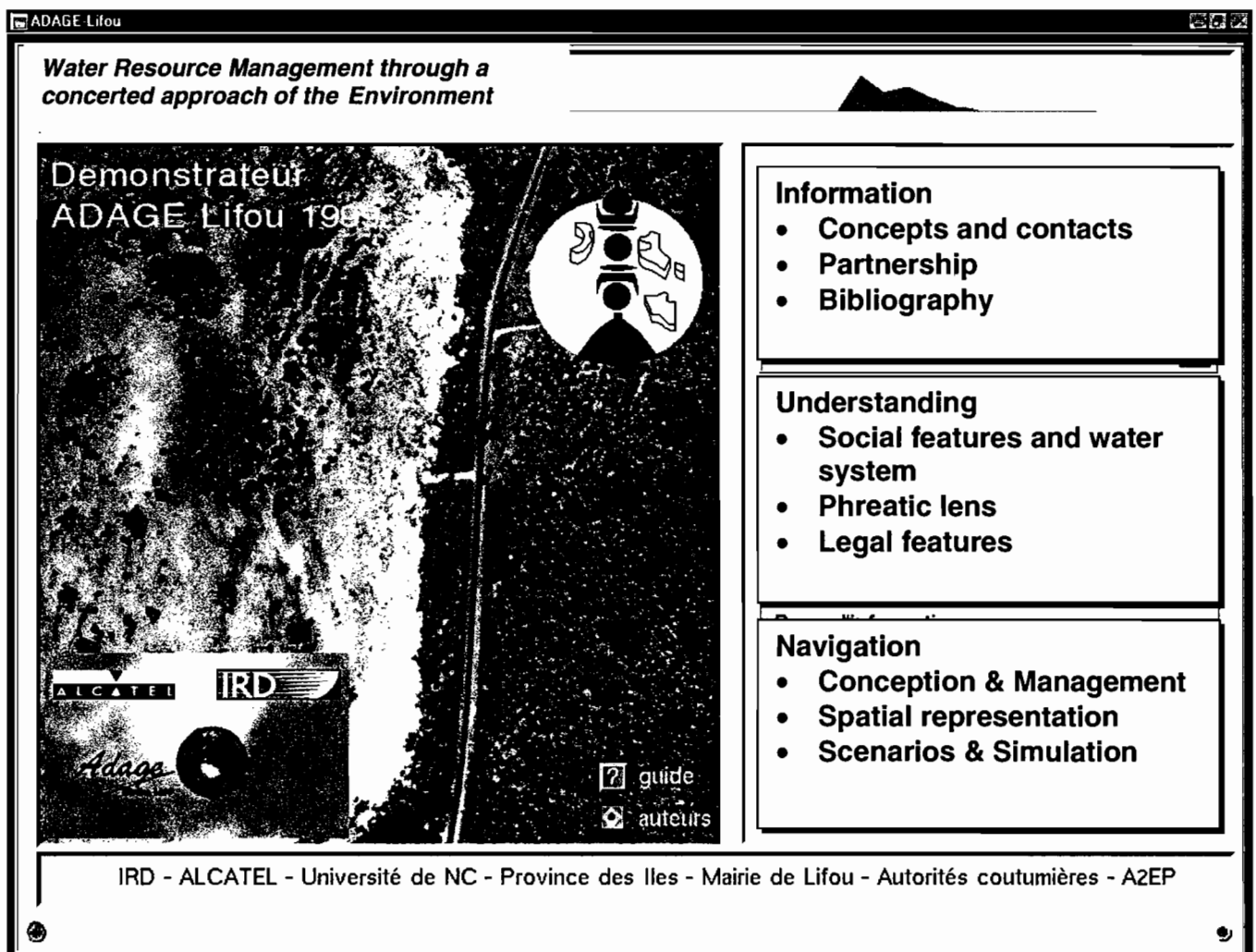


Fig. 7 The dashboard of the demonstrator

Description and use of the demonstrator tool – the GIS interface

A graphic layout, a «Geographic Information System » type :

- predetermined information layers by experts,
- a basis of data georeferenced and object oriented,
- links with INTERNET.

Sensitivity maps may be exploited differently in the decision process:

- static and compartmentalised presentation of the information, like an atlas,
- crossing of information within a system of geographic information (in particular, crossing between aggression and vulnerability),
- dynamic modification enabling the simulation of an evolution of the sensitivity.

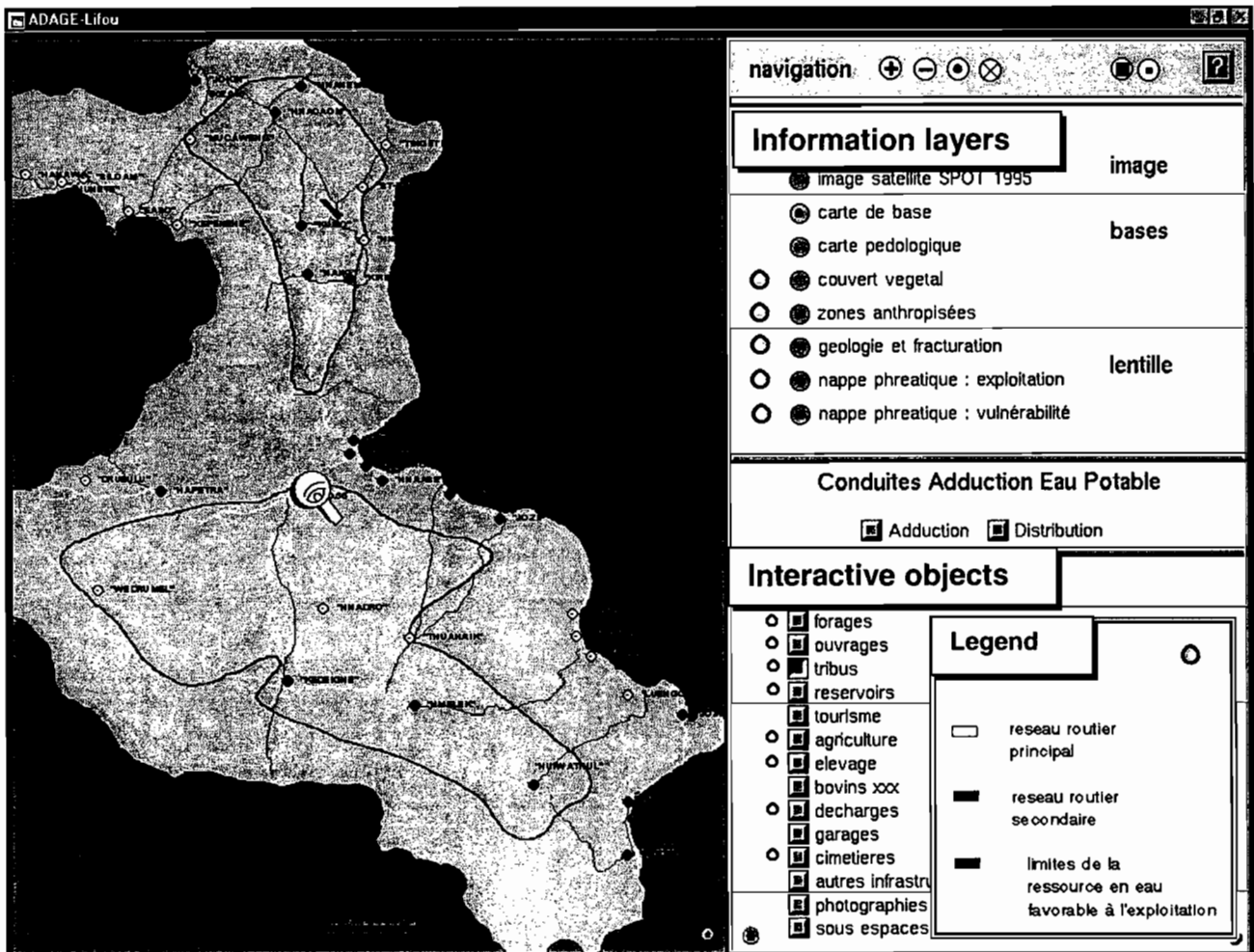


Fig. 8 Part of the GIS interface

Integration of the information layers specific to the risk notion :

- vulnerability of the environment,
- allocation of the resource and limits of exploitation.

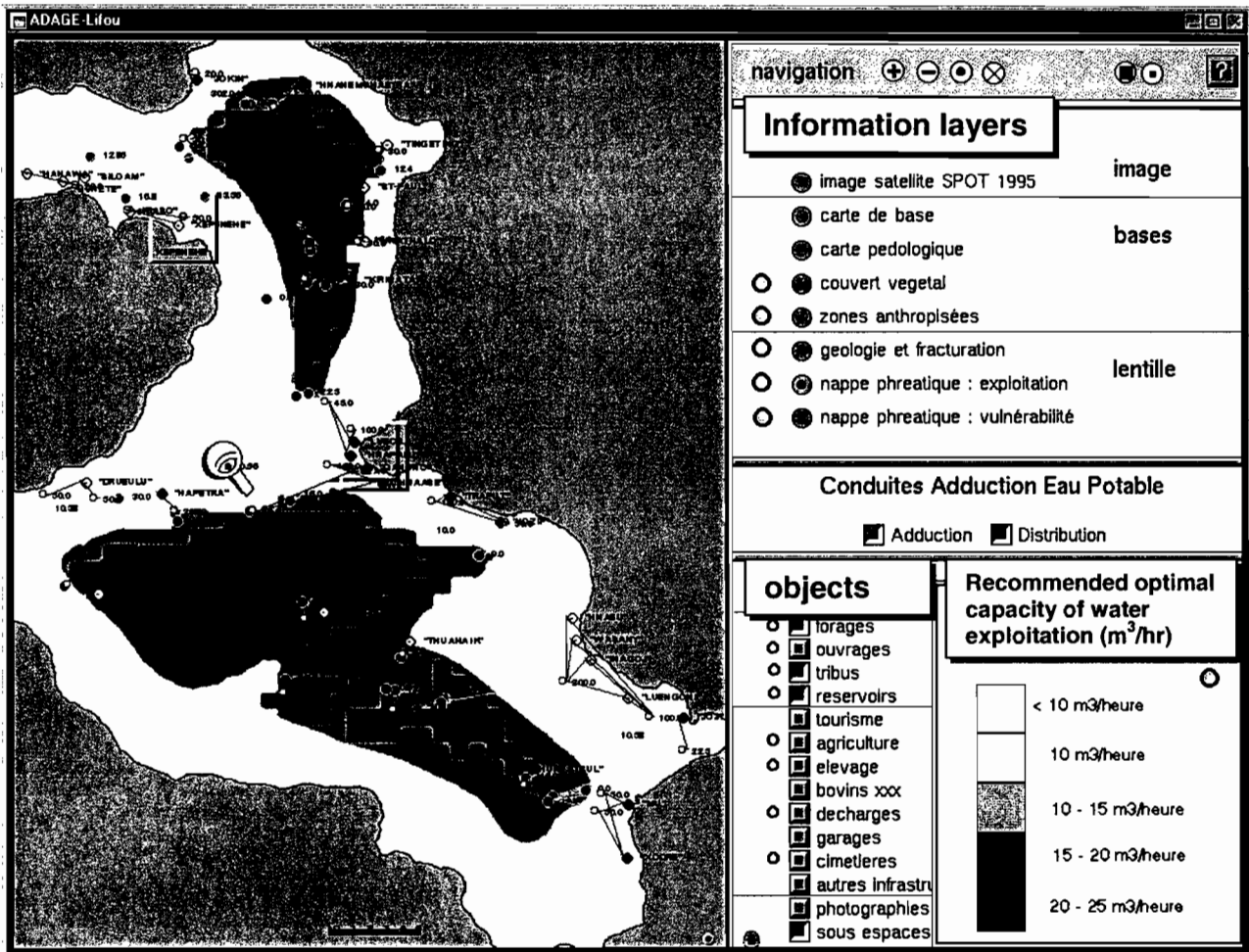


Fig. 9 Integration of the information layers specific to the risk notion

Major functioning principles of the LIFOU soft water lens³ :

Lifou is the largest of the high carbonated islands composing the « Archipel des Loyauté ». It stretches according to a NW-SE direction, parallel to « la Grande Terre ». It is made up of limestone build on a volcanic substratum, which does not show on any part of the island surface, but acknowledged by geophysics. Schematically, it is a raised atoll supported by age basalts dating back between 9 and 11 million years. The summital reef crown of the island which shows the beginning of the uplift of the island belongs to the inferior Pleistocene period.

³ Source: Michel Allenbach, in charge of the geological study in ADAGE-Lifou project - University of New-Caledonia

The description of the rocks showing on the surface of Lifou enables to distinguish three types of limestone facieses forming two main geomorphologic units :

- the limestone build upon the reef crown of the previous atoll to be found at the island 's periphery.

- the biomicritic limestone and the biomicritic dolomite are the expression of a lagoon sedimentary filling of an old atoll located in the inland part.

Therefore, the porosity of these rocks is different and the rapid lateral variations do not allow an assimilation of this aquiferous environment to a homogeneous one. This makes it even more complex to explain its functioning.

The general case of the coastal aquiferous areas :

In most cases, the coastal aquiferous areas are connected to the sea. They are complex aquiferous/sea systems. In such systems, the underground soft water, which flows from there upstream to the downstream of the ground water, heads to the shore where it drains itself. Its progression is limited in depth due to the invasion, in opposite direction, of the sea water which tends to get under the continent. But due to their specific and differing density, these two types of water to be found at a time in the littoral area tend not to mix up. They will actually be superposed. The soft water being less dense " will float " above the more dense sea water.

The contact between those two water types is shown by a transitional area more or less thick according to local configurations. Its location is determined by a modification of the height above the sea (in fact a difference between the hydraulic charges) between the piezometric level of the ground water and the zero level (seas average level).

An intense exploitation of the underground water in coastal areas, with flows above those of supply, debilitates the piezometric surface. The difference between charges lowers then and the sea water progressively flows into the aquiferous areas. This shows how important it is to manage with preciseness the exploitation of coastal ground waters.

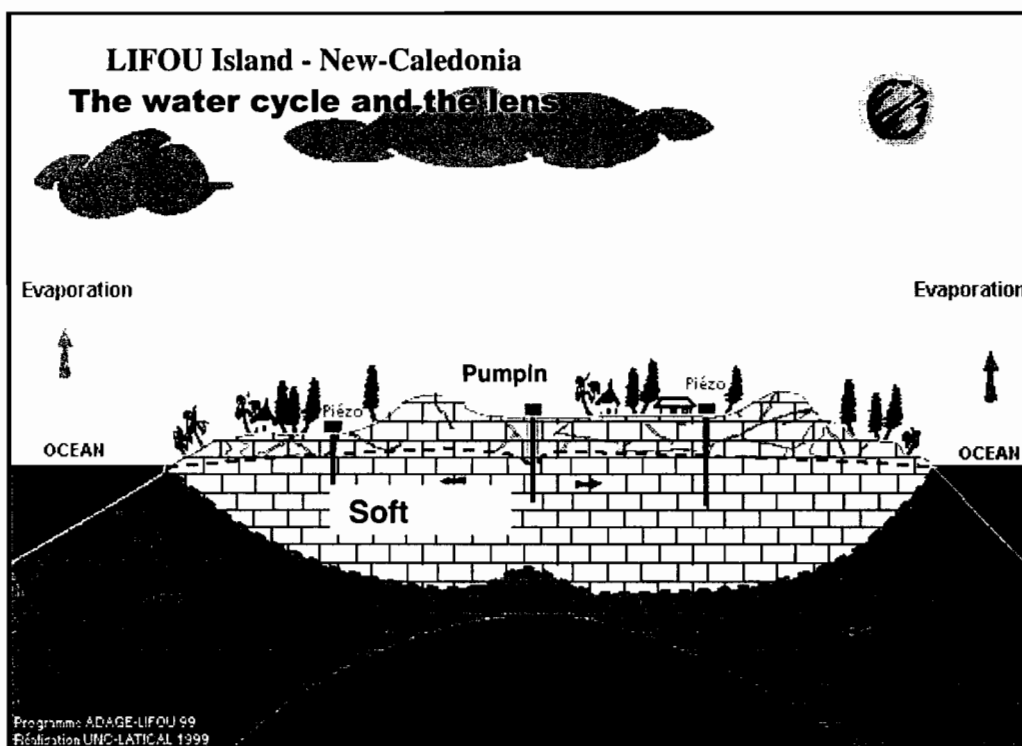


Fig. 10 The water lens of Lifou island

Integration of technical information on water networks :

- water conveyance network,
- water supply network,
- characteristics of the equipment (water tanks, drillings),
- simulations of flux

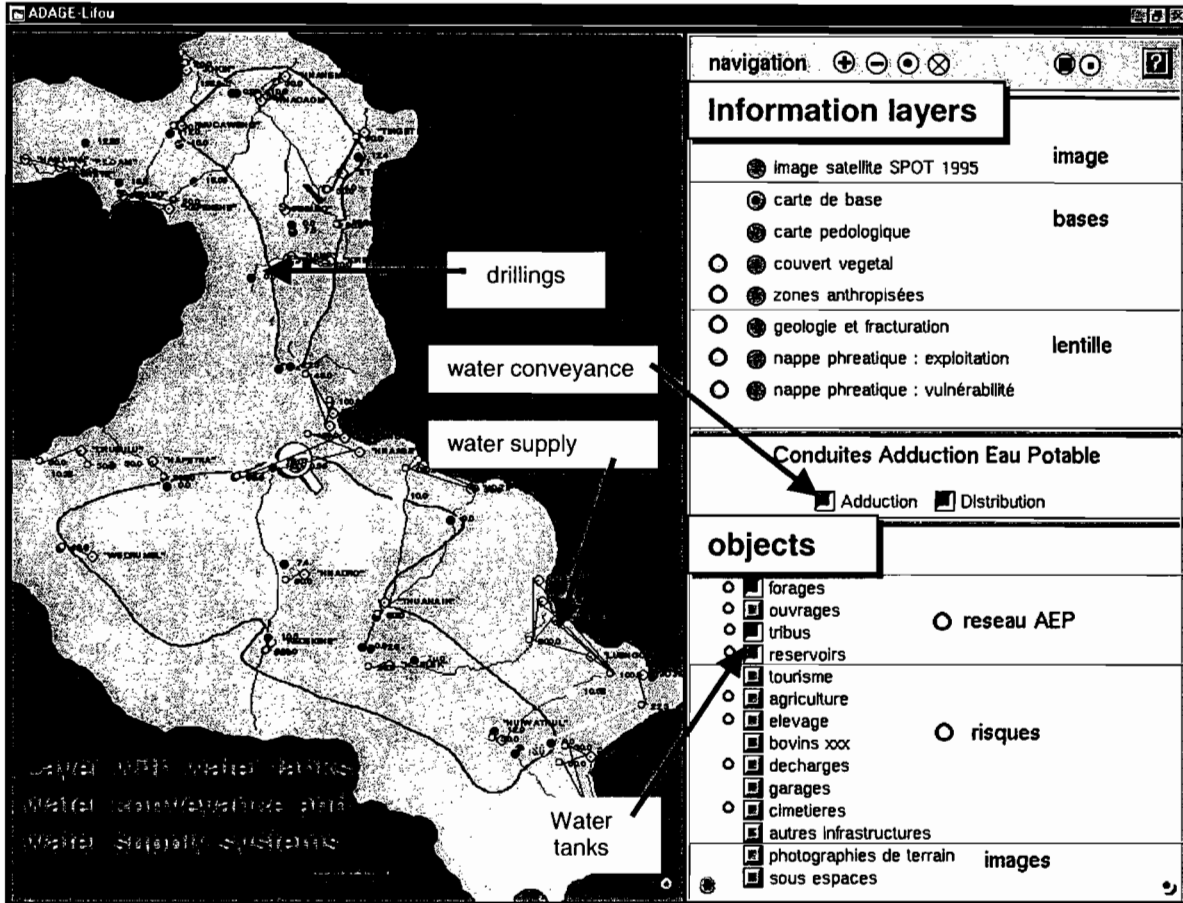


Fig. 11 Integration of technical information on water networks

Population 's distribution

An intrinsic temporal dimension:

- ability to simulate behaviours of entities
- ability of evolution in real time
- ability of building up sequential evolutive reviews

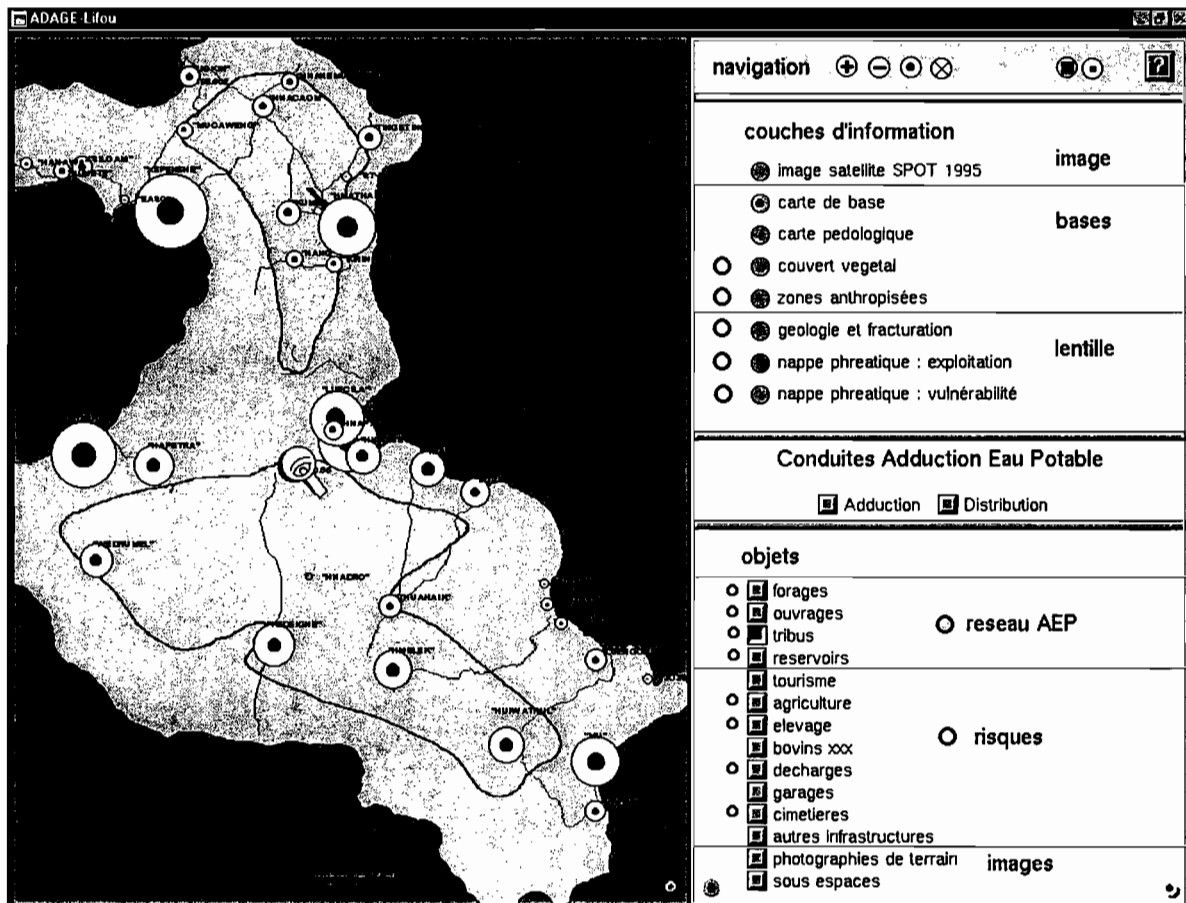


Fig. 12 The distribution of the population

Population and Demography

At the scale of an island like Lifou (1150km²) with an average population density of only 8.4 inhabitants per square kilometre, the demographic pressure on the environment and on the resource remains very weak, in comparison with other islands of the Pacific, such as Guam, Tahiti or Oahu. Despite a relatively weak demographic growth of 2.0% per year, the unequal spreading of the population, the extension of the occupied areas, the increase in the number of the infrastructures consuming water, the increase of the needs and the equipment of households, the development of tourism are nevertheless as many factors contributing to an acceleration of the drawing outs of the water reserve. They also multiply rejects which can possibly affect the ground water.

Internal Average Relative Reflectance

This dialog is used to convert raw DN values to relative reflectance. This is done by dividing each pixel spectrum by the overall average spectrum.

To open this dialog, select **Image Interpreter | HyperSpectral Analysis... | IAR Reflectance...** .

Input File: Enter the name of the input file or click on the File Selector button. The default file extension is .img.

Output File: Enter the name of the output file or click on the File Selector button. The .img extension is automatically added.

Coordinate Type: Click the appropriate radio button to select the type of coordinates to use. If the input file does not have map coordinates, the coordinate type will automatically default to File.

Map Click to use map coordinates, if the data are rectified.

File Click to use file coordinates, which are pixels, starting with 0,0 in the upper left corner.

Subset Definition: Use this group to define a rectangular area of the data to be used as the output file. The coordinates of the subset may be derived from an inquire box in the Viewer or by entering explicit X,Y values for the upper left and lower right corners of the subset. The default coordinates are the entire input file.

From Inquire Box Click to define a subset area of the data by using the Viewer Inquire Box. When you click this button, the coordinates below are updated with the coordinates of the cursor box in the Viewer.

To change these coordinates, you can move and/or resize the cursor box in the Viewer, then click this button again.

i The image you are using and the inquire box must already be displayed in a Viewer in order to use the From Inquire Box option. Otherwise, you may manually enter coordinates in the fields below.

UL X: Upper Left X coordinate

UL Y: Upper Left Y coordinate

LR X: Lower Right X coordinate

LR Y: Lower Right Y coordinate

Ignore Zero in Output Stats. When this check box is on, pixels with zero file values will be ignored when statistics are calculated for the output file.

OK Click to run this program with the options selected and close this dialog.

Batch Click to include this function in a batch file.

AOI ... Click this button and the Choose AOI dialog will display. This dialog lets you select an AOI (area of interest) in the image to which to apply this function.

Cancel Click to cancel this process and close this dialog.

View ... Click this button and a Model Maker window will open and display the graphical model used for this function. You can edit the graphical model from this Model Maker window for a specific use.

You can also edit the Spatial Modeler Language script through the Model Maker window (select Process | Generate Script from the Model Maker menu bar).

Help Click to see this On-Line Help document.

⇒ For information on using the ERDAS IMAGINE graphical interface, see the on-line **IMAGINE Interface** manual.

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