Information and Communication Technology as a means to improve stakeholders understanding of the Commons : The case of Groundwater Management in France[i]

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Introduction

As Ayres and Kneese (1969) [1] among many others point out, water – as well as air – beyond its free good characteristics is a common property resource (*res comunes*). "*Water and air are traditionally examples of free goods in economics. But in reality, in developed economies they are common property resources of great and increasing value presenting society with important and difficult allocation problems which exchange in private market resolve*"[ii] French law on water (1992)[2] recognizes water as "the common patrimony of the nation". In practice, this law defines institutional structures (SDAGE[iii] and SAGE[iv]) in order to manage and maintain the resource overtime through consultation, cooperation and dialogue, and not only using competitive private market systems for water. While SDAGE concerns the management of water resources at a large hydrographic scale, the SAGE refers to the management of related components within a hydrological system (i.e. rivers, streams and aquifers) However, resource management techniques and modalities are not uniformly defined which, at large, depend on the prevailing institutional context at a local level, on the specific physical resource characteristics and on the local actors *viz.* consumers, environmentalists, hunters, fishermen and representatives of local administrations. Groundwater is, therefore, a resource that brings together a great number of water users, namely, stakeholders.

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[ii] Ayres R., Kneese A.V. (1969), p. 283.
[iii] SDAGE: Schéma Directeur d'Aménagement et de Gestion des Eaux (Scheme Guide for the Management and Development of Water Resources).
[iv] SAGE: Schéma d'Aménagement et de Gestion des Eaux (Scheme for the Management and Development of Water Resources).

Traditionally, conflicts arising from a lack of understanding among stakeholders are a major problem when dealing with common property resources and more generally environmental issues. In some cases, the conflicts have been solved by congregating stakeholders and discussing the divergent interests that have eventually led to a better management of the resources. Improving and integrating the quality of information and common knowledge would accelerate the process of mutual comprehension. Therefore, we aim at exploring the introduction of Information and Communication Technologies (ICT) as a tool for improving the understanding of stakeholders in the management of a Common Pool Resource : Groundwater.

Understanding the multivariate dimension of water management can be improved through the application of innovative ICT. This methodology is able to combine hydrological, spatial and economic data sets which could be integrated within scenario simulation tools. This approach allows robust and clear scientific support for deliberation by decision-makers and stakeholders permitting intelligent compromises and co-operative conflict resolution.

1. Commons, Common Property and stakeholders' participation

Confusion surrounding the concept of Common Property is probably due to Hardin's seminal paper on the tragedy of the commons (1968)[3] and to the following debates[4]. Bromley (1992)[5] asserts « *In the literature on natural resources and environmental policy, it would be difficult to find an idea (that is, a concept) as misunderstood as "commons" or "common property"* »[i]. Many authors still think that Common Property Resources are, by their very nature, subject to vulnerability. According to Ciriacy-Wantrup and Bishop (1975)[6], the concept of Common Property follows two characteristics :

- Distribution of property rights in resources in which a number of owners are co-equal in their rights to use the resource. This means that they are not lost through non-use.
- Potential resource users who are not members of a group of co-equal owners are excluded.

Consequently and because of the very large number of users, exploitation of the resource might lead to a partial or total overexploitation of the resource if no instrument or mechanism for management is institutionalized. An institutional mechanism would lead us to a durable management of the common property resource, hence finding the adequate institutional governance structure remains the main "problem" of the Commons.

The management of Common Property Resources, such as groundwater implies a number of conflicting interests arising from a lack of understanding and agreement among various users of the resource (industry, agriculture, consumers…). These disagreements and misunderstanding arise from the differences between user's needs: agriculture needs water for irrigation, industry needs water for the industrial process and others consumers need water for drinking, washing, cleaning, and for others individual uses. Moreover, there is a great difference of quantity needs among users. Agriculture water consumption, in some cases, represents about 70% to 80% of the total consumption of water.

For instance, french farmers does not pay for irrigation, while consumers pay for the water they drink, increasing socio-political conflicts. Thus, it is often argued that a participatory form of governance can produce a better management of the resource, for the following reasons:

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[i] Bromley, D. 1992, p. 3.

- First, we can find reasons closely linked to the public perception of environmental problems. Environmental problems appear more and more complex, uncertain, they imply long term issues, and they are often irreversible and global : scientists and policy makers cannot always find by themselves a solution about the problems in debate. However, this does not imply that uncertainties have recently increased but we can state that political and scientific controversies had never had the current attention and public awareness. The participation of NGO's in international environmental agreements has contributed, through media, to increase common citizen local participation, which usually acts as a silent non-participatory group and is often regarded as weak actors.

- Second, the idea of Sustainable Development (see for example principle 10 of the Rio declaration) also implies direct participation from the public. Increasingly, citizens and others stakeholders express less trusting attitudes towards politicians in charge of public amelioration of society. Besides, stakeholder feel powerless before its institutions. It is proven though that citizens are not as naïve as most of politicians or scientists think[7]. Politicians normally do not take into account the public opinion about common property resources which can sometimes, determine the priorities of action. In this view, it is argued that a new form of citizenship is coming to the fore. Democracy cannot only be representative or delegated but concrete and direct because politicians, and even NGO's, do not represent correctly public's aspirations. Summarizing, we could say that the whole question of legitimacy is in debate.

- Third, public participation in environmental management structures can generate a better assessment of risks. The measures chosen by citizens take into account more efficiently citizen's preferences and needs. Moreover, there can also be more creativity in the debates and decisions. The process of dialogue also leads to a better information and more transparency about citizen needs, political strategies and about the problems at stake. It is also possible to reduce the number of conflicts arising from a lack of information, and reduction of the costs of conflict resolution.

- Finally, public participation in environmental decision-making would ameliorate political trust and generate, in the political process, a possible reduction of future controversies because stakeholder discussions force to return to the foundations of collective action.

To summarize :
Environmental stakeholder decision-making processes, if public participation is fairly organized, could :

1. **Augment collective learning** : This type of procedure allow a better diffusion of information among stakeholders;
2. **Avoid conflicts** : This type of procedure can help to produce a reasonable reconciliation of the conflicting interests;
3. **Integrate the weak actors into the stakeholder group** : This type of procedure can integrate in the discussions the views of (economically, socially) weak actors such as consumers;
4. **Reveal social demand** : With the presence of weak actors, a participatory governance procedure of management can reveal the basic needs of people;
5. **Enable contradictory debate** : This type of procedure is not exclusively dedicated to consensus in a first step and can put the stress on existing conflicts. Thus, discussion between the various stakeholders can raise contradictory debate.

6. **Increase democracy** : All the above elements themselves are part of the democratic system.

2. Towards an analytical framework for the « commons »

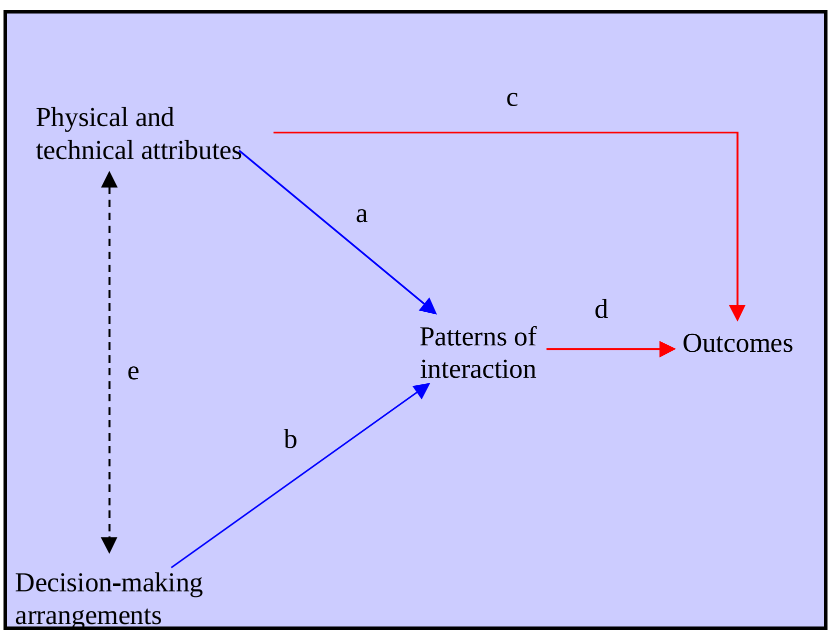
In order to manage the commons sustainably, it is important to establish who are the users of the resource, the conditions of its use and the legal framework that determine the modes of use and appropriation of the resource. The legal framework refers to the institutional actors in charge of regulation and enforcement.

Oakerson (1992)[8] proposes an analytical framework for the commons built on four attributes allowing to analyze a commons :

- Physical and technical attributes,
- Decision-making arrangements,
- Patterns of interaction,
- Outcomes.

Data information can be used to distinguish the above four attributes and focus our attention on the connections established between each one as well as to analyse their internal relationships. On the one hand, Oakerson[i] argues that (a) and (b) are weak causal connections: "*weak in the sense that individual behavior is constrained, but not determined, by either the physical world or by rules*". On the other hand, causal connections (c) and (d) are stronger "*because human discretion is not involved as a dependant variable*" (see Fig. 1).

Figure 1: A conceptual framework to analyse the Commons



[Source : Oakerson (1992), p. 53.]

3. An illustrative case concerning the Beauce aquifer

[i] Oakerson R 1992, pp. 52-53

Using Figure 1, we will attempt to adapt Oakerson's conceptual framework general idea to our case study, but we will not strictly follow the interrelationships maintained between attributes because the SAGE has not yet reached its final stage.This section will, therefore, partly use Oakerson' framework to present the Beauce aquifer case study :

- Physical and technical attributes,

The calcareous Beauce aquifer (which contains an average stock of 20 billion m^3) is situated between the areas of Etampes, Chartres, Châteaudun, La Ferté Saint Aubin, Blois, Melun, Montargis all of them in France (see Map 1). This area is one of the biggest producer of cereals in Europe, this proves the economic importance of the region. Most of the area presents limestone characteristics, in others words, the geological features of the terrain facilitates the infiltration of water rain into the aquifer.
The hydrodynamics of the aquifer are estimated to be the following[9] :

Estimated inflows and outflows balance in average year (in million m^3)

Outflows	Total	Total	Inflows
Individual and industrial consumption Irrigation Outflows to Loire-Bretagne rivers basins Outflows to Seine-Normandie rivers basins	100 250 300 250	900	Rain
	900	**900**	

[Source : DIREN Centre, AELB, DIREN Ile-de-France, AESN, 1998]

Estimated inflows and outflows balance in a drought year (in million m^3)

Outflows	Total	Total	Inflows
Individual and industrial consumption Irrigation Outflows to Loire-Bretagne rivers basins Outflows to Seine-Normandie rivers basins	100 450 150 150	100	Rain
	850	**100**	

[Source : DIREN Centre, AELB, DIREN Ile-de-France, AESN, 1998]

The tables above show that consecutive drought years (see graph 1) can eventually lead to an important reduction of the water balance and, therefore, an important negative effect on the ecology system, economy and society of the Beauce region in general.

- Decision-making arrangements,

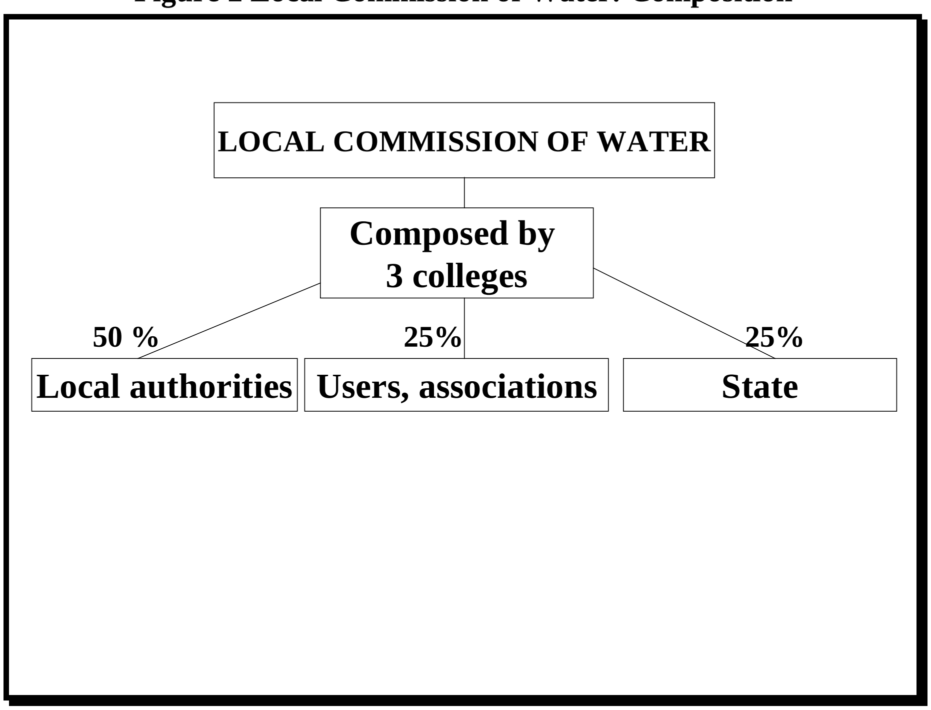
Regarding the institutional administration of the aquifer, this has a quite peculiar and strategic position because the aquifer occupies six local "departements" (*Eure et Loir, Loir et Cher, Loiret, Seine et Marne, Yvelines, Essonne*) ; two regions (*Centre* and *Ile de France*) and two regional water basins (*Loire-Bretagne* and *Seine-Normandie*). Each of these local institutions should take into account the Ministerial directive, which, if fact, include various Ministries, in order to sustain the aquifer. However, the local institutional role is also to represent a variety of stakeholder and their interests within the region, increasing, therefore, the discrepancy between what is needed and what should be done. Given that the Beauce aquifer is one of the most important aquifer of France in terms of volume and needs, the institutions in charge of the aquifer have different and unlinked responsibilities causing, therefore, conflicts of interest at all levels of the hierarchical governance structure appear.

In addition, a three-years period of dramatic droughts between 1991 and 1994 and conflicts arising from water quality degradation have increased the social awareness regarding the sustainability of the resource. Consequently, regions "*Centre*" and "*Ile de France*" decided to prohibit irrigation on Sunday at the beginning of the 90's. But this system was not really accepted by the farmers and in 1997, the idea to launch a SAGE project on the Beauce aquifer appeared to be the best consensual solution.

- Patterns of interaction,

SAGE is an institutional innovation established in 1992 by the water law. The main idea is to gather all the stakeholders that are interested in the resource management at a local level in order to collectively define the priorities of management from a sustainable perspective. Although the State has a role concerning the management of all French aquifers, the SAGE is an open institution that welcomes initiatives from all stakeholders. The SAGE consists of a local user committee, namely the Local Commission of Water[i], which is composed by representatives of the State (25%), local authorities (50%) such as the region, the water agency and representatives of civil society (25%), associations, users…, all in charge of the decisions concerning the aquifer.

Figure 2 Local Commission of Water: Composition



A SAGE process consists of four steps:

[i] Commission Locale de l'Eau.

The emergence phase is the first step of the process. A small group of users or representatives of the state (or the local authorities) brings in a project of SAGE to the prefect.

Second, the research phase. Here, the prefect launch a large consultation and orders the perimeters of the SAGE (i.e. Map 1) and the formation of the Local Commission of Water.

The third step is the elaboration of the official document. The Local Commission of Water would try to establish an inventory of the resource, draws up a global diagnosis, explores the scenarios and tendencies, and chooses a strategy of management.

The last step of the process is the publication of the SAGE document. This document reveals the priorities of management, the amount of investments engaged and the rights and duties of users.

- <u>Outcomes.</u>

The users of the Beauce aquifer are still today engaged in the SAGE second step process, that's it, delimitation of the aquifer perimeter (see map 1). The Local Commission of Water has not yet been chosen, but we expect that the process of stakeholders engagement is done in a transparent manner and supported by the existing information about the Beauce aquifer. Information and Communication Technologies such as Geographical Information Systems can help to improve management strategies and allow to emerge a common appropriation of the problem through common knowledge.

4. GIS technology in the Beauce context?

One of the most important challenges facing natural resource managers today is to identify, measure, and monitor the cumulative impacts of land use decisions across space and time. Perhaps in no other field are these challenges more apparent than in water management, where different categories of use decisions are shaped by numerous competing and often conflicting claims on the natural resource base. Because water management encompasses the simultaneous consideration of hydrological, pedagogical, and biological resources, the need for making better use of analytical tools and approaches which address spatial and temporal variability is critical. One family of information technology products that has gained widespread acceptance among natural resource and environmental managers in the developed world is Geographic Information Systems (GIS).

New and more sophisticated technologies such a GIS technologies have been developed in the past recent years. These new computerised technologies have been improved in numerous scientific domains. Management itself is a multidisciplinary field which demands new tools to improve and augment the scientific knowledge performance for a better management. Water management requires the help of specialists such as hydrologists, geographers, farmers (especially needed in ground water management) geologists, economists, etc. Each specialist has a different point of view concerning the aquifers and new technologies allow us to integrate the specialists' common knowledge in order to augment the socio-economic efficiency of water. Participatory models of management for decision making enrich the regulatory process by giving a broader information and knowledge of the sustainable needs of a natural resource[10] that, in our case study, would lead to a more appropriate local regulations for water management. All in all, GIS increase democracy among the participatory stakeholders groups by contributing to a more economically and proficient management regime with improved efficiency and efficacy.

Water management and its use results from complex decision-making processes in which various type of information are involved. Geomorphology, water ways, rivers, road, location of towns, villages, railroads, agricultural and urban areas, figures on market prices and many other parameters will be useful to take into account, so to get a better idea of the best choice for policy making. The hydrological system, economic value, and its increasingly exploitation and pollution risks problems lead us to a complex situation in which decisions for rational and sustainable water use becomes highly difficult.

Computerised information systems based on spatial location of water resource and its attributes are powerful new tools for management. The locative information permit us the analysis of large amount of essential information, statistical and temporal data, necessary to generate information products in the form of maps as well as tabular and textual reports for water use decision[11]. GIS is a computerised tool that uses multipurpose water resources information systems, which can be utilised in a rapid and efficiently way to generate various kinds of information according the requirements of different users.

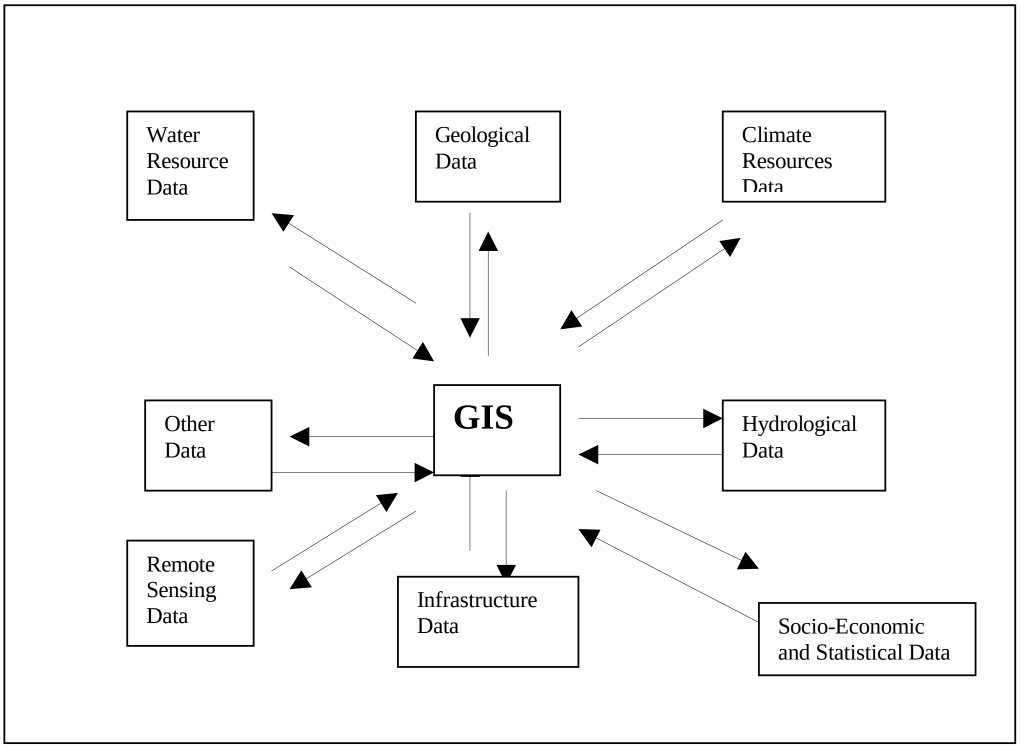
GIS stores data in the form of maps that have the following main qualities:

(a) capacity to overlaying, manipulate, joining and desegregating;
(b) capacity to test future scenarios according to scientific hypothesis;
(c) capacity of represent two-dimensional or three-dimensional location of earth characteristics including those in the atmosphere, and four-dimensional processes (space/time).

GIS is therefore a multidisciplinary instrument which integrates databases models for data analysis, decision support tools, computer hardware and software and the human resources and institutional framework, and it is often organised in the form of network (see figure 3).

In the case of groundwater management, by mapping and modelling the aquifer conditions, such as inflows, pollution risk, salinity, morphology of the aquifer, we can create a GIS remote sensing data support. If data is precise and regularly updated, remote sensing enables us to monitor the future of an aquifer which is an important (if not essential) element of water degradation assessments and determinant for the sustainability of the aquifer[12].

Figure 3.



[Source: Sombroek, W.G. and J. Antoine (1994). The Use of Geographic Information Systems (GIS) in Land Resources Appraisal]

A combination of various data on the physical aspects of the aquifer will result in a water resource database and cognitive mapping that will permit us to identify the most optimal rate of water extraction from the aquifer at each point, so to avoid causing any adverse effect to agriculture, water consumers, biodiversity and the overall economy of the region. By cognitive mapping we understand a developed map representation with a rich understanding of a complex situation by representing the cause-effect relationship that are perceived to exist between the elements within its environment[13]. Cognitive mapping provides a means of defining and representing the problem space and is particularly useful in ill-structured situations where user's understanding of the organizational context may be lacking or else exists only at a tacit level. Therefore, GIS estimates the changes either in water use sustainability or in environmental degradation hazard that arise from a scenario being tested. The broader the evaluation is the better the results and exactitude could be achieved. The opposite would remain a serious drawbacks in the implementation of measures for increased water exploitation, sustainable management and conservation of natural resources and environmental monitoring. Furthermore, and using Pomeroy's definition of co-management, GIS could be perceived as a tool for co-management: "Co-management covers various partnership arrangements and degrees of power-sharing and integration of local- and Goverment-level management systems. It involves some degree of communal management of the resource"[14].

In the context of the *Nappe de Beauce* (Beauce Aquifer) we have recently known that the use of GIS (Mapinfo[i]) is bound to the location of water extraction point. Neither we could find studies or data that could be used to monitor and understand better the Beauce water resource and its most near future, surprisingly the tools to perform numerical maps are provided but, as said, not used. Since our case study is "an empirical enquiry" that investigates the stakeholders phenomenon within its real-life context, the use of information and technology is justified in groundwater management conflict resolution[15]. Especially in this case where boundaries to which they are exposed are not well defined and clearly evident, and it relies on few source of evidence. The logical boundary of an information system is defined by the location of the resources from which it obtains inputs, of users to whom it provides outputs and entities to which the information in the system pertains[16]. Broadly speaking, based on its boundary, an information system may be characterised on a continuum from local to global. Even though they may not be an instance of a purely "local" or "global" system, it is important to explicate the characteristics of these archetypes to understand and appreciate the differences between the design, development and implementation of information systems that are hybrids of local and global characteristics. As for example, in the case of the Beauce aquifer, we can find precipitation data sources at a local level[17] whereas some of the economic data are only accessible at the regional level[18].

5. From comprehension to representation : GIS technology; multi-stakeholder assessment

The identification of elements of a problem and understanding and explaining how they interact with one other is a fundamental aim of groundwater management. Two areas that seem to be relevant to this "moving along" from comprehension to representation, namely (1) understanding the problem situation and (2) user involvement. It is the depth and quality of this understanding that underpins, first, the identification of information and from these the selection of appropriate and meaningful solutions.

Data concerning future investments should be stored and therefore mapped. The benefits of additional geologic information are computed by comparing the economic impact of decision that would be made using the new map information relative to decisions base on existing map data. Additions to geologic map information are show to have a net positive social value when used in a regulatory setting[19]. Many of the current GIS studies have shown to be efficient when a map information is develop to improve the understanding among users of such a tool[20]. Moreover, it is proven that GIS users will experience shorter solutions and fewer errors given the same level of task complexity[21]. Finally we could say that GIS tools currently seem to be the most suitable tool to aid in the management of available hydric resources[22].

6. GIS constraints

The main limitations when using GIS are:

- Lack of data or poor data quality which remain important in the implementation of computer-based systems of water management.

[i] Mapinfo is a GIS software with a low capacity for decision making.

- Lack of computing skills personnel to apply the systems in solving practical problems which often causes the available systems to be under-utilised and sometimes not used at all.
- Software products are changing rapidly. The use of one software for a special case might be recommendable or not when dealing with a study, it will depend on whether the personnel is informed of the most recent software that suit better the special case, so the lack of information about most suitable software is a serious constraint.

- Local support and maintenance is often of variable quality[23].

- Digital information technology is developing faster than research and water organisations can keep pace.

- Data collection and records should be precise and objective in order to obtain a good final result of a study, that's it, being objective and realistic merits special attention from a best-choice policy perspective, and still remains a very serious constraint.

- Continuous and available data recording. Data should be regularly updated in order to reduce to the minimum level the errors from not available and statistical data.

- Available technologies. Unfortunately developing countries will not be able to purchase computerised technologies resulting in a bad management that will have important negative effects to the economy and society[24].

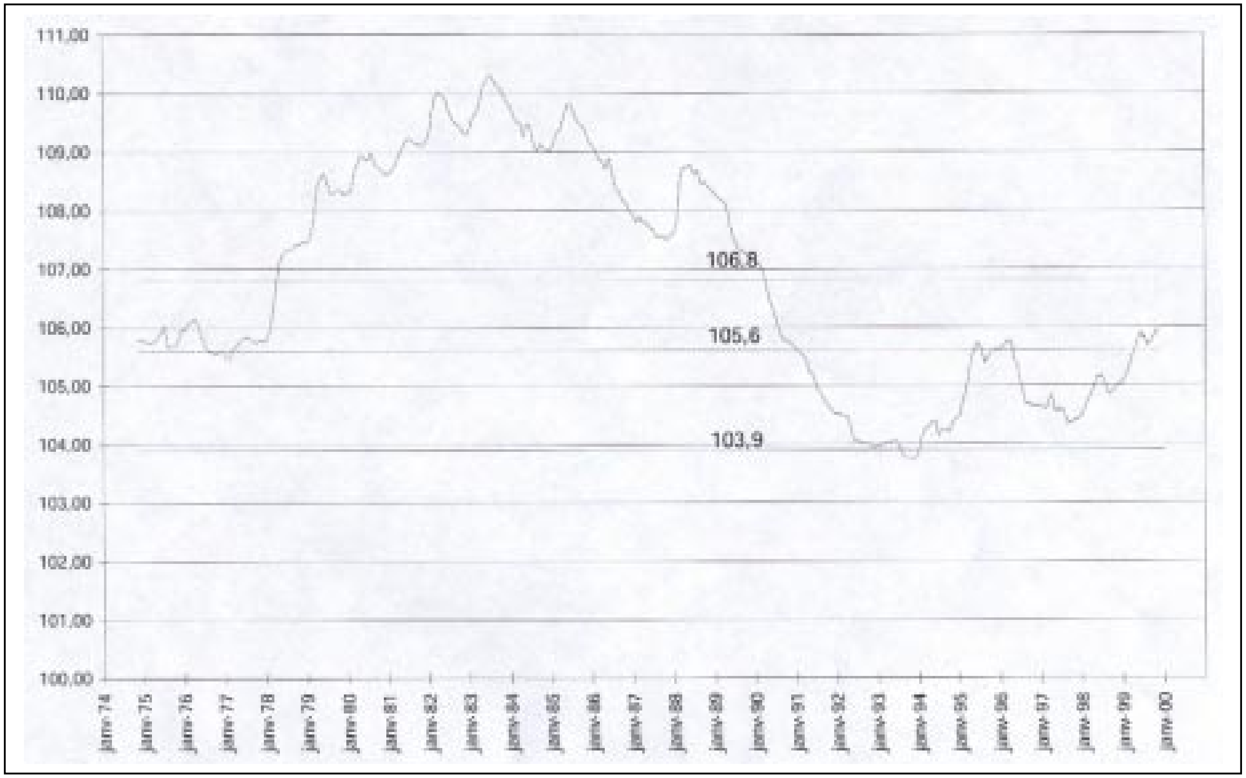
Conclusion

Technological and institutional innovations require well organised infrastructures systems to diffuse information relative to a common resource. Common property resources present interesting characteristics for the study and experimentation of new technologies innovations and its diffusion. Democracy, that's it, an increase of the stakeholders participation facing a common property resource problem has led us to a major number of public participants in the decision making process. The introduction of more sophisticated technologies and institutional innovations permit us to integrate educational and pedagogical ways of accommodating new management techniques.

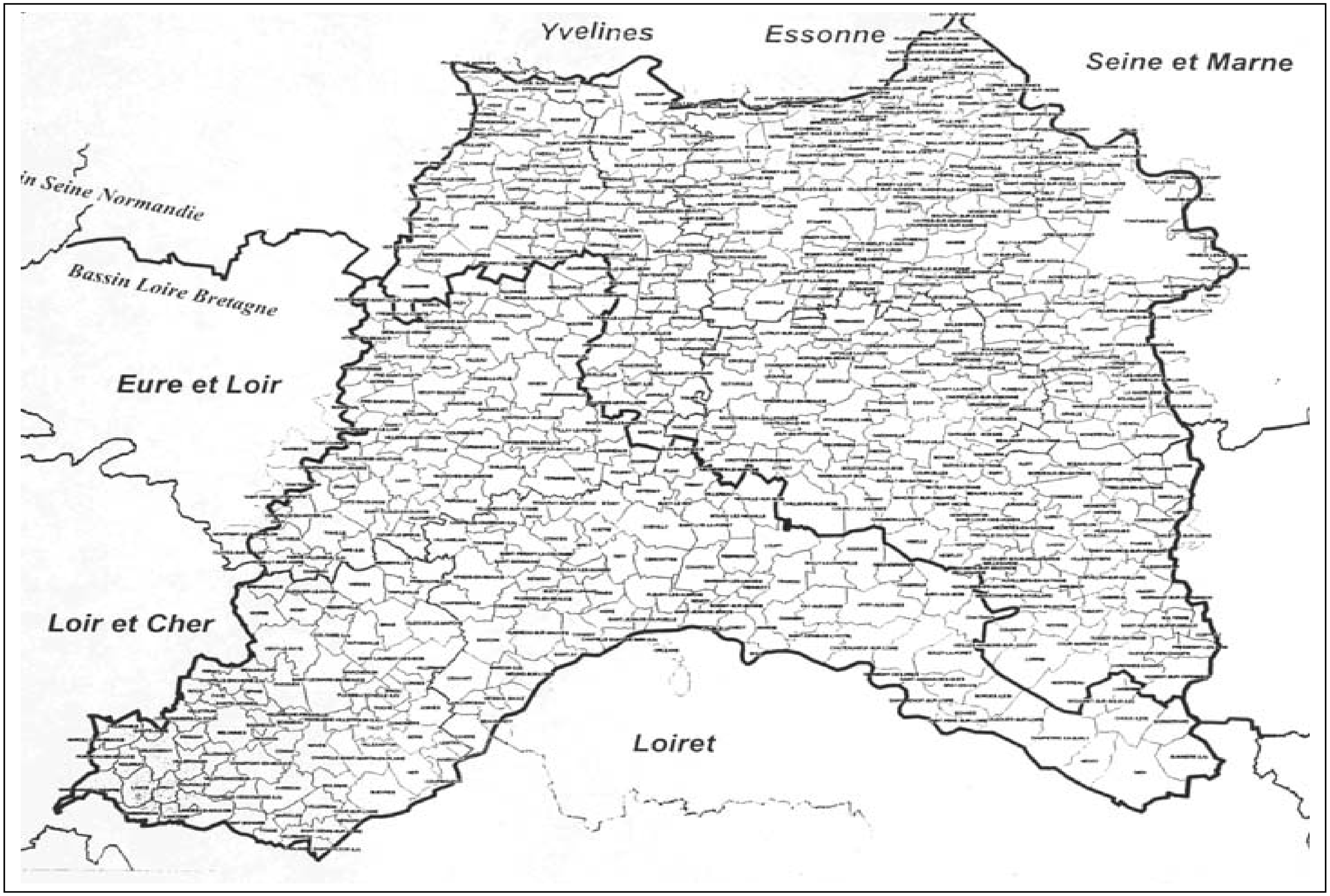
GIS technologies allow us to geographically locate, and taking into account the present and future risks of the resource, the best option choice for policy making given a specific scenario. It is for this reason that we believe that GIS tools are pertinent for facing water management sources. However, GIS data should be objective, precise and comprehensible in order to avoid uncertainties, and specially in the Beauce context that management presumably deals with groundwater and uses large amount of statistical data.

All in all, the Beauce aquifer seems to be an interesting case study for the communal nature of the aquifer. This paper has intended to prove the challenge that underground water management poses when considering participatory stakeholders in the policy making process, as well as introducing in this process institutional and technological innovation.

Graph 1: Beauce aquifer average water level from January 1974 to January 2000.



Map 1: Perimeter of the Beauce aquifer elaborated by the SAGE.



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