INFLUENCE DU MODE D'UTILISATION DU SOL SUR LES CARACTERISTIQUES CHIMIQUES DE CERTAINES SOURCES AQUIFERES

Didier Martin
D.E.S.S. d'Aménagement du Territoire

l'Institut pour la Forêt et la Nature
Leersum

FACULTE DE SCIENCES ECONOMIQUES DE POITIERS

INFLUENCE DU MODE D'UTILISATION DU SOL SUR LES CARACTERISTIQUES CHIMIQUES DE CERTAINES SOURCES AQUIFERES

Mémoire de fin d'études du D.E.S.S. d'Aménagement du Territoire présenté le :

Par : Didier MARTIN

Stage effectué à l'Institut pour la Forêt et la Nature de Leersum (Pays-Bas) du 2/05/95 au 15/08/95

Acknowledgements

I want to thank Professor Dr. W. J. Wolff for his acceptation to receive me to do my research in the Aquatic Ecology Department of the "Institute vor Bos en Natuur".

My thanks are going also to Dr. L.W.G. Higler and to Dr.ir. P.F.M. Verdonschot for their explanations on my work, and their availability to share their experiences and knowledges on nature management.

I am also grateful to J.A.Schot and to M.W. van den Hoorn for their help, especially in computer use.

Thank you also to the other members or vulunteers of the institute who have contributed, like the first one to make this training period nice for me.

Furthermore, I am also grateful to Professor Guesnier who has permitted me to get a financial help and who has encouraged me to have this foreign experience.
Finally, I thank M.Saumet, our environment teacher, who has accepted to follow my study and to give to me some advices.

PREFACE

- The Netherlands, a country with contrasts

Even if this small country, composed by twelve provinces, is not far from France, many things are totally different. The freedom image that we have in France towards this country hides, in reality, a really well organized country, with people aware that they are a lot on a small country and so that many stricts rules and a good discipline are totally necessary. Furthermore, the dutch history shows a good solidarity of the nation to fight against water either to create new polders or to avoid floods which can be very dangerous in a so flat country (for example in 1953, water killed almost 2000 people especially in Zeeland province). Dutchs are also famous for their power in trade (Rotterdam is the biggest harbour in the world), and for a very modern agriculture which comes from a really good soil (fat and easy to work because of the relief, of the stones absence and of the water presence (the Netherlands is composed by 400000 kilometers of canals and ditches)). This flat country provides a strange landscape with many meadows surrounded by water where especially cows are raised (the international "Friesland cow"), and in some areas with fields of flowers (especially tulips). The mills presence in all the west part of this country shows us that the wind blows often. The east part is a bit a different : some small hills appear and forests have been planted in some parts.

- My attraction for a work there

Before to come in this country for this training, I knew a bit Holland by some travels here. But it was always for short periods and I wanted to come back to stay longer to know better the dutch way of live. My studies in planning this year and my previous agricultural studies have offered to me the possibility to try to apply for a training on an environment project. So, I have sent different letters and I came in Marsh to see people and finally in April, I received the positive answer from the IBN-DLO, which means the Forestry and Nature Institute which depends on the agricultural research service from the agricultural, nature behaviour and fishery dutch ministery. The letter from Bert Highler was very cosy and explained to me that the project for my work "should handle the relationship between land utilization and infiltration areas, and fits in a programme for investigation and quantification of helokrene sources and seepage areas in a predominantly agricultural landscape. The ultimate goal is the protection and restoration of helokrene sources". After an ask for a financial EC help and their positive answer, I have decided to go to The Netherlands for this work fom the beginning of May 1995 to normally the end of July, but finally the middle of August.

- An introduction to the "Dienst Landbouwkundig Onderzoek" (DLO) and to the"Instituut voor Bos-en Natuuronderzoek" (IBN).

Twelve technologically advanced research institutes, over 3200 specialized workers, and an almost countless number of subjects, ranging from apples to zymase and aquatic ecosystems to zooplancton. DLO-NL is working in all these fields. The problems arising in agriculture, horticulture, forestry, fisheries and nature management are becoming more and more complex, creating the need for scientific excellence and socially acceptable solutions. DLO provides a meaningful and essential contribution to agriculture in the broadest sense.
In an international sense, DLO is also 'pushing back agricultural frontiers'. On a regular basis, projects are handled in collaboration with 'sister- institutions' in other countries. In addition, relationship with developping countries are becoming more and more significant. The DLO organization possesses a wealth of knowledge that can be of importance to these countries.
DLO research is carried out for the national government -in particular the Ministry of Agriculture, Nature Management and Fisheries- for provincial and local authorities, and for the European Union (EU).
Furthermore, large and small companies provide a growing part of the research budget.
The DLO scientists attempt to help the decisionmakers of both government and the business community to make choices.

At present, DLO is still part of the Ministry of Agriculture, Nature Management and Fisheries .Project groups,strategists and management are, however, preparing the organization for independence.DLO will become a more market-oriented organization with a mixed clientele. But the main objective of DLO research will still be to achieve sustainable and competitive agriculture, horticulture, forestery and fisheries,and a habitable countryside.

The DLO is divided in different institutes located mostly in Wageningen. These one are the following :

- Agricultural Research Department (DLO-NL)
- DLO Research Institute for Agrobiology and Soil Fertility (AB-DLO)
- DLO Agrotechnological Research Institute (ATO-DLO)
- DLO Centre for Plant Breeding and Reproduction Research (CPRO-DLO)
- DLO Agricultural Mathematics Group (GLW- DLO)
- DLO Institute for Forestry and Nature Research (IBN-DLO)
- DLO Institute for Animal Science and Health (ID-DLO)
- DLO Institute of Agicultural and Environmental Engineering (IMAG-DLO)
- DLO Research Institute for Plant Protection (IPO-DLO)
- DLO Agricultural Economics Research Institute (LEI-DLO)
- DLO Centre for Agricultural Publishing and Documentation (PUDOC-DLO)
- DLO State Institute for Quality Control of Agricultural Products (RIKIL-DLO)
- DLO Netherlands Institute for Fisheries Research (RIVO-DLO)
- DLO Winand Staring Centre for Integrated Land. Soil and Water Research (SC- DLO)

DLO has a Central Office in Wageningen called Agricultural Research Department (DLO-NL) which is responsible for the continuity of the organization, and plays a stimulatory and managerial role in keeping to the strategic course. The staff departments in this office coordinate activities and support the institutes in personnel and financial matters, communications-management and computer science. The research strategy department coordinates and initiates national and international research.

DLO-Nl research is covering the following fields :

- crop protection
- plant breeding
- animal health
- animal breeding
- nutrients
- nature and environment
- product safety
- quality and processing of products
- socio- economic development
- administration and management (for instance, development of information and management systems for agricultural enterprises)
- techniques, technology and labour

The field of my training concerns nature and management, and so the institute in which I study, is the IBN-DLO. This organization carries out research into nature in the widest sense of the word. In town and country areas, in terrestrial and aquatic areas and from local to international scales. Its work comprises nature protection and management, forestry and urban ecology. The institute also develops methods for applying the research results.

This institution is divided in different departments :

- vegetation ecology
- ecotoxicology
- animal ecology
- aquatic ecology
- landscape ecology
- natural resources management
- management and administration
- international affairs

The aquatic ecology department of IBN-DLO works on the maintenance, restoration, development and management of nature in the sea, fresh and brackish waters. It also performs scientific research and develops methods to apply the results of its own and others' research. It aims to contribute towards a responsible use of natural waters and wetlands, both for nature protection and multi-functional use. It carries out national and international research topics : estuaries, North Sea, running fresh waters, moorland pools and fens, micro- and meso-cosms, computer modelling.

Thus, it is organised in three parts :
- fresh waters managed by L.W.G. Higler, my research responsible
- salt waters managed by N. Dankers
- coastal and sea birds managed by B.Ebbinge

This aquatic department is managed by Professor W.J. Wolff. The amount of people working in this department turns around 30 permanents but is often more because of the presence of some volunteers and trainees who are welcome to help the team.

-The Institute location

Except the salt waters part located on Texel Island, the two other parts and the head of this department is located in Leersum in the Utrecht province .
Leersum is a small town (7000 inhabitants) at 20 kilometers west from Utrecht, at 20 kilometers east from Wageningen and at 35 kilometers east from Arnhem. It means that this institute is located is the Netherlands center and very close to Wageningen, the only city in this country so much axed on agriculture and nature (agricultural university, research institutes (for example, headoffice of DLO...)). The freshwater section rents a part of a castle in Leersum and so the area is very nice with a ground composed by grass, forest and a pond. Around there is a mixed landscape with pastures, forests and small villages. This area is a very residential and nice houses and castles are frequent. So, the forest is giving an other view from the dutch landscape that foreigners are used to remember.

-The freshwater section organization

This section is managed by Bert Higler assisted by Piet Verdonschot. Its aim is to characterize biological aspect of freshnaturalwater and especially, by the macrobiotic identification, they arrive to know how polluted or not a water is . Three permanent people are helping these biologists for this aim. Furthermore, two people are working on a programm with artificial ditches, and one is more specialized for vegetable identification.
Programms can be ordered by private or by public companies. My study was ordered by the quality water organization from the Limburg province, that is by a public company.

-Calendar of my training

During the first month, I got informations on freshwater by reading some books in the library, and on the work of the institute. At the end of May, my study was precised by Piet : to determinate on maps the catchment areas of springs from Limburg that they identified in April, and to see their land use in two periods (1950 and 1985) to be able to compare this soil utilization. I realized this work in June and in July . Then to go on the fields with the team and to take some criteria and some water samples for a chemical analysis, that I should have done, but finally a labaratory has done it.This practical work was realized during the second week of July.
At the end, the purpose was to join land use and chemical analysis and to see, if there is, or not links between these two elements, what I did in August.
Material and help from people were possible to get when I needed. I was working in an office that I have shared at first with a chinese researcher and then I was alone in this room with my own computer.

TABLE OF CONTENTS

INTRODUCTION

The Netherlands are a very densely populated country with highly cultivated and industrialized areas. In such conditions, nature can be easily affected and it is necessary to have some strict policies to avoid problems.
Water quality in this country depends on the provincial policy (department of water management) and so according to the needs, a differentiated approach can be done per province.
In some few areas, it still exists some natural physico-geographical areas, and springs are often located in such places.
Limburg province which is a quite natural province, has so some springs on it territory.
The water quality shows us that springs, similarly as streams, contain too many chemicals and it is interesting to know if there is a relation and for which element, between chemical concentration and land use which composes the catchment area of the spring . Such information can indicate what activity is responsible for a kind of pollution and can prevent either to avoid to do an activity on a land, either to maintain that one but with a try of pollution reduction.
A long time (two and half month) at first was passed to collect all these informations to work with, which are totally new, concerning both land use on catchment areas on two different periods and some chemical water datas.
We are not going in our study to compare chemical concentration with some levels to see if these concentrations are too high for human and nature. Tolerable levels change in each country and often, in time per country and so has, a relatively meaning. Hence, land use and chemical tables will appear without too much commentaries on the amount of each criteria per spring. Furthermore, my technical water knowledges aren't big enough to be able to realize such a discussion.
Thus, our study instead of to be technical will be more economical, using correlation coefficient and Principal Component Analysis. These methods appear complementary in their results but the second one permits us to compare furthermore land use and chemicals with springs.
So, our different steps in our work will be at first to define the catchment areas for our springs, then to characterize it land use. The water chemical datas will be obtained in a second part, and finally, in a third part, we will be able to use the previous methods to see links between elements and to discuss on this point.

DEVELOPMENT

-What is a spring ?
"Springs occur where groundwater aquifers discharge at the surface. According to their morphology, area and volume of flow, springs are divided into four categories described as rheocrene, limnocrene (Bornhauser 1912), helocrene (Steinmann 1907), and arkocrene (Tolkamp 1983)".
In the province of Limburg helocrene springs were the more numerous.
"A helocrene spring is formed when a small volume of groundwater discharges more and less constantly over a relatively large, slightly sloping area. This area, called a spring source, becomes marshy with patches of vegetation on beds of organic material which are water saturated and from which, small spring streams arise. This results in a mosaic of substrates, each providing a habitat for several faunal groups (Thienemann 1912, Illies 1952, Thorup 1966, Thorup and Lindegaard 1977)": extract from "ecological characterization of surface waters in the province of Overijssel" (The Netherland).Piet Verdonschot 1990.

- Study location
Limburg province is located in the south east part of The Netherlands and is capital is the famous Maastricht city. But our study is located in the north of this province between Nijmegen and Roermond, and there is 80 kilometers between the northest one and the southest one and some are very close to the german border. The number of springs we had to work on, is 46.

1 The physical analysis

1.1 Catchment area

Our first work was to determinate the water catchment area of these springs on maps. So, we have taken differents topographical maps (9) at the scale of 1:25000 and after to copy and to make them bigger, we have used the contour lines to try to determinate step by step catchment areas .
The area is delimited by the topographic divide, a theoretical line which passes through the highest points around the spring. However, it is one vision of catchment areas for these springs, and so that is that water has so many ways to come from, that is very difficult only on maps to try to see from where it comes, and so determinations can be numerous.
We have arrived to different sizes of catchment areas depending on the relief.
In some cases, like for spring number 14, the land is so flat that we couldn't use the contour lines but have used ditches to limit our catchment area. On the other hand, it was easier to know the water way when the slope was steep (spring number 1...).

1.2 Land use

The second work was still with maps to determinate the land use on these catchment areas.
To realize this part, we had to use the copy maps sheets and to reproduce on each catchment area all the different informations like varied colours, points, strokes. A color copy could have been useful to avoid this step, but there was no.
Then we have counted with a square plastic pattern the amount of various land use elements which compose each catchment area : numbers of mixed forests, deciduous forests, coniferous forests, paved areas, arable lands, meadows with ditches, glasshouses, trees nursery, heath, marshes and reeds, sand were the elements we have recorded.
Orchards have been considered as arable lands and paved areas as areas including houses but also roads and railways.
Then, it was after easy to calculate per area the percentage of each element.
To try to avoid the problem of working with different catchment areas sizes, datas have been collected not only in percentage but also in surface (square kilometer).
To be able to see the evolution of this land use, we have recorded datas from two periods : 1950 and 1985. Catchment areas are the same in these two different years, because contourn lines haven't changed. So, we had only to copy the first catchment area and to see the land use for this other year.
Results appear in next tables (tables 1 and 2).

Table 1. Distribution in percentage of land use from springs catchment areas of Limburg province around 1950.

Num.	Types	Maps years	Maps codes	Paved area	Mix.forest	Conif. forest	Decid. forest	Arab land	Mead ditch	Glas	Heath	Tree nurs	Mar.reed	Sand
1	Helo	1956	46B+E GROES.+GRENS.	0	7.5	32	50	2	0	0	8.5	0	0	0
2	Helo	1956	46B+E GROES.+GRENS.	5	0	27	14.5	39	14.5	0	0	0	0	0
3	Helo	1956	46B+E GROES.+GRENS.	0	18	24	30.5	13.5	14	0	0	0	0	0
8	Helo	1956	46B+E GROES.+GRENS.	0	0	50	50	0	0	0	0	0	0	0
9	Helo	1956	46B+E GROES.+GRENS.	0	0	3	64.5	23	9.5	0	0	0	0	0
10	Bronv	1956	46B+E GROES.+GRENS.	0	0	2.5	56.5	29	12	0	0	0	0	0
11	Helo	1956	46B+E GROES.+GRENS.	0	52	48	0	0	0	0	0	0	0	0
12	Bronv	1956	46B+E GROES.+GRENS.	0	52	48	0	0	0	0	0	0	0	0
14	Limno	1954	46 D BOXMEER	0	0	0	0	2.5	97.5	0	0	0	0	0
30	Bronv	1951	52 E MEERLO	0	32.5	48.5	12.5	4	1.5	0	1	0	0	0
53	Helo	1955	52 H SCHANDELO	9	0	7.5	14.5	63	1.5	0	4.5	0	0	0
55	Helo	1955	52 H SCHANDELO	23.5	0	0	59	15.5	1.5	0	0.5	0	0	0
56	Helo	1955	52 H SCHANDELO	25	0	0	49.25	23	2.75	0	0	0	0	0
57	Helo	1955	52 H SCHANDELO	16.5	0	0	29.75	49.25	4.5	0	0	0	0	0
58	Bronv	1955	52 H SCHANDELO	17.25	0	0	30	16.25	27	7.5	2	0	0	0
63	Helo	1951	52 H SCHANDELO	6	1.5	8.5	14	70	0	0	0	0	0	0
	Bronv	1951	58 F GASTHUISHOF											
64	Akro	1951	58 F GASTHUISHOF	19	1.5	0	4.5	70	2	0	2.5	0	0	0.5
66	Helo	1951	58 E TEGELEN	0	0	0	3	0	0	0	59.5	0	0	37.5
68	Limno	1951	58 E TEGELEN	0	0	0	3	0	0	0	59.5	0	0	37.5
71	Helo	1951	58 E TEGELEN	0	1	12	31	34	3.5	0	11.5	0	1	6
74	Akro	1951	58 E TEGELEN	0	19	35	6	25	0	0	15	0	0	0
75	Helo	1951	58 E TEGELEN	0	18.5	34	9	24	0	0	14.5	0	0	0
76	Helo	1951	58 E TEGELEN	0	18	33	11	23.5	0	0	14.5	0	0	0
79	Helo	1951	58 E TEGELEN	0	2	97	0	0	0	0	1	0	0	0
84	Limno	1951	58 E TEGELEN	0	2.5	88.5	6	0	0	0	3	0	0	0
85	Limno	1951	58 E TEGELEN	0	4	89	1.75	0	0	0	5.25	0	0	0
86	Limno	1951	58 E TEGELEN	0	5.5	89	0.25	0	0	0	5.25	0	0	0
87	Helo	1951	58 E TEGELEN	0	4.75	90	0.25	0	0	0	5	0	0	0
88	Helo	1951	58 E TEGELEN	0	3	86.5	1	0	0	0	7	0	0	2.5
92	Bhelo	1951	58 E TEGELEN	12	2	0	13	56	15	0	2	0	0	0
97	Bhelo	1949	58 D ROERMOND	5.25	0	0	0	56	38.75	0	0	0	0	0
98	Bhelo	1949	58 D ROERMOND	2,25	0	0	0	59,75	38	0	0	0	0	0
102	Bhelo	1949	58 D ROERMOND	24.25	0	0	6.75	61,5	7,5	0	0	0	0	0
	Bhelo	1951	58G+H SWAL.+GRENS.											
103	Bhelo	1949	58 D ROERMOND	15,25	0	0	27.5	49	1,25	0	0	0	7	0
	Bhelo	1951	58G+H SWAL.+GRENS.											
104	Bhelo	1949	58 D ROERMOND	11,75	0	0	0	32,75	55,5	0	0	0	0	0
	Bhelo	1951	58G+H SWAL.+GRENS.											
105	Bhelo	1949	58 D ROERMOND	24	0	0	11.25	31	33,75	0	0	0	0	0
	Bhelo	1951	58G+H SWAL.+GRENS.											
116	Bhelo	1949	58 B PANNINGEN	3,5	32	17	13	34,5	0	0	0	0	0	0
117	Bhelo	1949	58 B PANNINGEN	0	3.75	35,5	3	54	0	0	3,75	0	0	0
118	Bhelo,Limno	1949	58 B PANNINGEN	0	9.5	1	15	72	0	0	2,5	0	0	0
119	Helo	1949	58 B PANNINGEN	0	0	0	19.75	77,5	2,75	0	0	0	0	0
125	Bhelo	1949	52 B VENRAIJ	0	74	0	21	0,5	4,5	0	0	0	0	0
		1951	52 E MEERLO											
132	Bhelo	1949	58 D ROERMOND	0	44.5	36	9.75	0	0	0	9,75	0	0	0
134	Helo	1949	58 D ROERMOND	0	0	0	0	72,25	27,75	0	0	0	0	0
136	Bhelo	1951	52 G VENLO	4	0	0	32	60	4	0	0	0	0	0
150	Helo	1949	58 D ROERMOND	0	49	35.25	2.25	13.5	0	0	0	0	0	0
Total average in percentage				**4,97**	**10,18**	**23,95**	**16,13**	**27,93**	**9,34**	**0,17**	**5,29**	**0**	**0,18**	**1,87**

Table 2. Distribution in percentage of land use from springs catchment areas of Limburg province around 1985.

Num.	Types	Maps years	Maps codes	Paved area	Mix.forest	Conif.forest	Decid.forest	Arab land	Mead.ditch	Glas	Heath	Tree nurs	Mar.reed	Sand
1	Helo	1982	46 B GROESBEEK	0	0	49	49	2	0	0	0	0	0	0
2	Helo	1982	46 B GROESBEEK	12	0	20.5	23.5	12	32	0	0	0	0	0
3	Helo	1982	46 B GROESBEEK	0	0	42.5	33.5	9	15	0	0	0	0	0
8	Helo	1982	46 B GROESBEEK	0	0	0	100	0	0	0	0	0	0	0
9	Helo	1982	46 B GROESBEEK	0	13.5	4.5	57	24	1	0	0	0	0	0
10	Bronv	1982	46 B GROESBEEK	0	17	6	46	30	1	0	0	0	0	0
11	Helo	1982	46 B GROESBEEK	0	0	92	8	0	0	0	0	0	0	0
12	Bronv	1982	46 B GROESBEEK	0	0	92	8	0	0	0	0	0	0	0
14	Limno	1982	46 D BOXMEER	0	0	0	0	33.75	66.25	0	0	0	0	0
30	Bronv	1982	52 E BLITTERSWIJCK	0	1.5	84.5	9	3	0.75	0	0.75	0.5	0	0
53	Helo	1988	52 G VENLO	0	0	0	15	56.5	28.5	0	0	0	0	0
55	Helo	1988	52 G VENLO	42	0	6.5	51.5	0	0	0	0	0	0	0
56	Helo	1988	52 G VENLO	55	0	8	35.5	0	1.5	0	0	0	0	0
57	Helo	1988	52 G VENLO	63	0	19	16.5	0	1.5	0	0	0	0	0
58	Bronv	1988	52 G VENLO	12	0	16	41	5	26	0	0	0	0	0
63	Helo,Bronv	1988	52 G VENLO	32.5	5.5	1	17	20.5	16.5	3	1	3	0	0
64	Akro	1985	58 E TEGELEN	24	0	3	10	31.5	25	6.5	0	0	0	0
66	Helo	1985	58 E TEGELEN	0	0	0	95	1	4	0	0	0	0	0
68	Limno	1985	58 E TEGELEN	0	0	0	95	1	4	0	0	0	0	0
71	Helo	1985	58 E TEGELEN	38	1	15	26.5	19	0	0	0.5	0	0	0
74	Akro	1985	58 E TEGELEN	0	9	54.5	26.75	9	0.5	0	0.25	0	0	0
75	Helo	1985	58 E TEGELEN	0	8.5	52.5	29.25	9	0.5	0	0.25	0	0	0
76	Helo	1985	58 E TEGELEN	0	8.5	51.5	30.25	9	0.5	0	0.25	0	0	0
79	Helo	1985	58 E TEGELEN	0	0	65.75	34.25	0	0	0	0	0	0	0
84	Limno	1985	58 E TEGELEN	0	0	93.5	0	0	0.75	0	5.75	0	0	0
85	Limno	1985	58 E TEGELEN	0	0	97.25	0	0	1	0	1.75	0	0	0
86	Limno	1985	58 E TEGELEN	0	0	91.5	8.5	0	0	0	0	0	0	0
87	Helo	1985	58 E TEGELEN	0	0	79.25	20.75	0	0	0	0	0	0	0
88	Helo	1985	58 E TEGELEN	0	0	74.75	25.25	0	0	0	0	0	0	0
92	Bhelo	1985	58 E TEGELEN	12.5	0	0	36	30	20.5	0	0	1	0	0
97	Bhelo	1985	58 D ROERMOND	7.5	0	0	0.5	43.75	45.75	0	0	0	2.5	0
98	Bhelo	1985	58 D ROERMOND	10.5	0	0	1.5	36.25	44.25	0	0	0	7.5	0
102	Bhelo	1985	58 D ROER.,58G SWAL	27.25	0	0	6.25	21.25	45.25	0	0	0	0	0
103	Bhelo	1985	58 D ROER.,58G SWAL	10.75	0	0	23.75	17.25	42.5	0	0	0	5.75	0
104	Bhelo	1985	58 D ROER.,58G SWAL	20.75	0	0	20.75	0.75	57.75	0	0	0	0	0
105	Bhelo	1985	58 D ROER.,58G SWAL	39	0	0	18	23	20	0	0	0	0	0
116	Bhelo	1985	58 B PANNINGEN	5	0	51	12	24	0	0	0	0	8	0
117	Bhelo	1985	58 B PANNINGEN	4.5	0	35.5	5	55	0	0	0	0	0	0
118	Bhelo, Limn	1985	58 B PANNINGEN	3	0	18	26	38	15	0	0	0	0	0
119	Helo	1985	58 B PANNINGEN	5.5	0	0	12.5	43.5	38.5	0	0	0	0	0
125	Bhelo	1982	52 B VENRAY	0	8	76	16	0	0	0	0	0	0	0
		1982	52 E BLITTERSWIJCK											
132	Bhelo	1985	58 D ROERMOND	0	27.25	62	5.75	0	0	0	0	0	5	0
134	Helo	1985	58 D ROERMOND	2	0	0	2	79	16.25	0	0	0	0.75	0
136	Bhelo	1988	52 G VENLO	5	0	20	17	51	6	0	0	0	0	1
150	Helo	1985	58 D ROERMOND	2.5	0	86	0.5	4.5	5.5	0	1	0	0	0
Total average in percentage				**9,65**	**2,22**	**33,29**	**24,13**	**16,51**	**12,96**	**0,21**	**0,26**	**0,1**	**0,66**	**0,02**

1.3 Interpretation

Each percentage is giving to us an idea but it is necessary to see the all springs land use evolution before to try to interpretate correctly these figures.
We can notice that springs are located for around 50 % in forest areas and this percentage didn't change too much from 1950 to 1985 (50% to 59% in total).But in this period, forest has become less varied (less mixed forest, more coniferous and deciduous forest).
Furthermore, in 35 years it is important to see that paved areas have almost doubled (4,97% in 1950 and 9,65% in 1985). In some springs, this increase is high : spring number 57 had 16,5% of paved areas, and 49,25% of arable lands in 1950 and in 1985 this no more arable land and 63% of paved areas.
This constat of arable lands decreasing can be seen in the global result because it passes from 27,93% to 16,51%.
In the same way, heath has decreased and represents actually only 0,26% of land use.
Glasshouses haven't changed too much.
On the contrary, meadows with ditches have increased and marshes and reeds too. But it is difficult to interpretate this last increase because first marshes and reeds weren't easy to limit on maps and secondly these parts were scarce.
Similarly, the evolution of tree nursery and of sand area don't mean really something because of this scarcety.
If we let paved areas so, and group in nature all the forests, heath, marshes and reeds, sand and in cultivated areas arable lands, meadows with ditches, glaasshouses and trees nursery, we arrive to this conclusion :
in 35 years, nature has increased a bit (57,6% to 60,58), paved areas have almost doubled at the expense of cultivated areas which have decreased (37,44% to 29,78%).
Next table (table 3) shows us the effect of these groups only for the springs we will study for chemical datas on next step.

Table 3. View of this group effect on some springs.

Springs numbers	Springs codes	Paved areas (%)	Nature (%)	Cultivation (%)
1	023503P	0	98	2
2	023502P	12	44	44
3	023501P	0	76	24
8	023203P	0	100	0
10	023201P	0	69	31
14	022201P	0	0	100
55	018401P	42	58	0
57	018403P	63	35.5	1.5
66	018202P	0	95	5
75	018004P	0	90.5	9.5
76	018006P	0	90.5	9.5
79	018011 P	0	100	0
84	018007P	0	99.25	0.75
87	018005P	0	100	0
92	017301P	12.5	36	51.5
97	016701P	7.5	3	89.5
104	016601P	20.75	20.75	58.5
105	016602P	39	18	43
118	026301P	3	44	53
136a	031201P	5	38	57
136b	031203P	5	38	57
136c	031202P	5	38	57

So, we can divide this table in four springs categories:

- springs where nature dominates : numbers 1, 3, 8, 10, 55, 66, 75, 76, 79, 84, 87
- springs where cultivated area dominate : numbers 14, 92, 97, 104, 118, 136(a,b,c)
- springs where paved area dominate : number 57
- springs more equal : numbers 2 and 105

This first study has given to us a view from some physical elements which characterize these catchment areas. Now, it is nice to study what are the chemical characteristics of water from these areas.

2 **The chemical analysis**

2.1 Material and methods

Some elements of this study have been done by ourselves (ph, conductivity, current velocity, temperature(air+water)), light measurements) with some specific fields materials, and all the other chemical datas have been done thanks to a laboratory.
We had to collect water sample for it.
During our summer field springs investigation, we have been surprised by some areas : some "springs" were dried and others were wet areas, but not springs. The April investigation had permitted us to work on 46 springs, but only 22 from these one were recorded as really springs in summer.

2.2 Results

Codes meanings in next table (table4) and their units are the following :

Num. : spring number
Acid : acidity (mmol/l)
Aff1 : material dry weight(mg/l)
Alka : alkalinity (mmol/l)
Ca1W : calcium (mg/l)
Cd2W :cadmium (ug/l)
Cl3 : chloride (mg/l)Cr2W : chromium (ug/l)
Cu2W : copper (ug/l)
K25 : electric conductivity (uS/cm)
KJ3 : Kjeldahl nitrogen method (mg/l)
KW : kalium (mg/l)
Mg1W : magnesium (mg/l)
NaW : natrium (mg/l)
Nh3 : ammoniac (mg/l)
Nh32 : ammoniac (mg/l)
Nh4N : ammonium (mg/l)
Ni2W : nickel (ug/l)
No23 : sum No23+No2N (mg/l)
No2N : nitrite (mg/l)
No3N : nitrate (mg/l)
O2V : field oxygen measurement (mg/l)
O2VP : laboratory oxygen measurement (mg/l)
OFOS : orthophosphatus (mg/l)
pH : pH
pHv : pH from field
SO4 : sulphate (mg/l)
Temw : water temperature (°C)
Tfos : total phosphorus (mg/l)
TotN : total nitrogen : sum Kj-N +NO3-N+NO2-N (mg/l)
Zn2W : zinc (ug/)l

Table 4. Chemical values obtained on some springs.

Num	Acid	Affl	Alka	Bica	Ca1W	Cd2W	Cl3	K20	K25	Kj3	KW	Mg1W	NaW	NH3	NH32	NH4N	Ni2W	NO23	NO2N	NO3N	O2V	O2VP	OFOS	pH	pH.v	SO4	Temw	Tfos	TotN	Zn2W
1	0.29	12	0.2	<5	20.1	0.31	22	212	230	0.3	1.7	5.4	14.2	<0.01		0.3	<1	5	0.01	5	8	77.7	<0.03	6.94	6.66	30	13.2	0.1	5.3	<10
2	2.3	82	0.58	82	32	2.1	41	592	647	5.8	50	8	23.6	<0.01	<0.01	4.5	37	16	0.13	16	0.23	2.6	<0.03	6.42	6.28	84	17.9	0.2	22	91
3	0.31	21	0.17	<5	26.4	0.25	29	271	298	0.4	1.5	6.3	17.5	<0.01	<0.01	0.3	<1	8.5	0.01	8.5	10	98.9	<0.03	7.23	7.05	34	14.6	0.1	8.9	<10
8	0.35	8	0.34	<5	25.3	<0.05	28	257	283	0.3	2	7.2	15.3	<0.01	<0.01	0.3	<1	3.2	<0.01	3.2	8.9	88	<0.03	7.5	7	40	15	0.1	3.5	<10
10	0.8	<1	2.12	165	65.7	0.05	29	439	478	0.7	2.5	9.6	18	0.013	0.024	0.9	<1	1.7	0.07	1.6	5.6	66.1	<0.03	7.77	7.51	61	21.7	0.12	2.4	<10
14	.37	19	0.15	21	64	0.97	30	523	568	0.4	9.5	10	15.7	<0.01	<0.01	0.4	5.3	35	0.07	35	2.2	23.4	<0.03	6.84	6.07	63	17.7	0.1	35	25
55	0.21	11	0.14	6	29.4	1.1	21	324	366	0.6	7.5	11.2	15.3	<0.01	<0.01	0.6	17	10	<0.01	10	7.4	70.8	<0.03	5.86	5.63	86	13.4	0.08	11	69
57	0.14	24	0.19	<5	24.9	0.9	26	278	314	0.9	5.4	8.2	21.8	<0.01	<0.01	0.5	13	5.7	0.01	5.7	8.1	82.6	<0.03	6.83	6.53	63	16.4	0.08	6.6	100
66	1.22	49	0.6	108	90.4	0.44	37	608	684	0.8	4.1	10.7	22	<0.01	<0.01	0.6	8.6	12	<0.01	12	8.4	79.5	<0.03	7.45	7.42	154	12.8	0.08	13	10
75	0.72	4	0.25	67	53.3	0.62	31	396	431	0.2	1.3	8.8	12.3	<0.01	<0.01	0.2	<1	9.6	0.01	9.6	2.9	25.8	<0.03	7.39	6.62	66	10.5	0.08	9.8	<10
76	0.64	20	0.23	<5	54.3	<0.05	33	416	502	0.9	2.5	9.6	14.4	<0.01	<0.01	0.3	2.7	15	0.03	15	7.4	83	<0.03	7.56	6.8	68	18.3	0.06	16	<10
79	0.75	32	0.22	62	37.9	0.09	17	244	280	0.7	1.2	6.3	10.7	<0.01	<0.01	0.5	5	0.8	0.01	0.8	7.5	69.8	<0.03	7.35	7.11	43	12.7	0.08	1.5	<10
84	0.32	8	<0.1	<5	33.8	1.8	25	340	375	0.5	2.9	10	14.9	<0.01	<0.01	0.2	16	7.7	0.02	7.7	6.4	67	<0.03	5.2	4.93	94	18	0.06	8.2	120
87	0.89	9	<0.1	<5	26.3	0.18	17	280	328	0.3	2.5	10	10	<0.01	<0.01	0.4	18	7.1	<0.01	7.1	7.9	80	<0.03	6.46	5.5	81	11.9	0.06	7.4	18
92	0.48	36	0.17	37	68.1	0.44	18	484	532	0.4	10.3	6.9	13.6	<0.01	<0.01	0.4	9.2	29	0.01	29	3	27.6	<0.03	7.35	5.49	91	13.2	0.14	29	22
97	1.38	75	0.32	92	101	0.27	36	603	661	0.4	0.6	6.7	16.7	<0.01	<0.01	0.5	6.3	27	0.02	27	2.3	22.8	<0.03	7.82	7.06	82	13.9	0.26	27	37
104	0.23	95	0.16	23	29.7	0.28	17	238	266	2.4	2.9	5.3	10.6	<0.01	<0.01	0.8	3.9	3.4	0.02	3.4	2.1	20.3	0.04	6.54	6.36	63	13.4	0.2	5.8	11
105	0.23	42	0.17	31	29.5	0.2	17	238	266	1.2	3.1	5.3	12.7	<0.01	<0.01	0.8	2.9	2.6	<0.01	2.6	5.2	52.3	0.04	6.98	6.76	57	15.8	0.14	3.8	10
118	0.26	116	0.11	<5	69.6	0.64	43	673	747	2.1	4.1	27.5	23.8	<0.01	<0.01	0.8	48	52	<0.01	52	3.1	31.9	<0.03	5.84	5.57	85	11.5	0.14	54	33
136a	0.59	13	0.18	49	116	0.17	35	770	842	0.2	9.9	17.8	15.5	<0.01	<0.01	0.4	4.2	41	0.01	41	2.8	26	<0.03	7.56	6.87	165	12.3	0.12	41	20
136b	0.45	46	0.18	<5	65	0.14	37	504	554	0.4	9.5	10.7	19.4	<0.01		0.3	9	18	<0.01	18	2.9	27.4	0.04	7.42	6.75	100	12.3	0.16	18	20
136c	0.58	80	2.02	150	105	0.86	50	650	716	1.3	10	11.2	28.9	<0.01	0.015	0.5	11	16	0.07	16	6.8	68.9	0.07	8	7.5	102	17.4	0.42	17	110

For unknown reasons, two datas are missing for NH32 column.
The sign < has been given before some figures when the material used was not enough precise to be able to determinate the good value.

3. **Links between land use and chemical results**

We have to compare table 3 and table 4. Two methods are going to be used in this aim.

3.1 The linear correlation method

3.1.1 Method description

To see if a relation exists or not between these two analysis springs, we will use the linear correlation, and if the coefficient is big enough we will represent on a graph the straight line.
Correlation coefficients (r) appear in table 5 (where land use appear in X axe and chemical datas on Y axe).
The more "r" in absolute value is close to 1, the better the correlation is.
Springs number is still the same : n=22.
The critical value table permit us to find the degree of meaning of these figures.
For three risks . 5% (significantly), 1%(highly significantly) and 1/1000(very highly significantly), and with n=22, we can give to each correlation is meaning.
This one can be non significantly(NS), significantly(S), higly significantly(HS), or very higly significantly (VHS). To be "S, HS, or VHS" with n=22, "r" values have to attain respectively 0.4227; 0.5368 and 0.6524 (figures given by the critical values correlation coefficient table).
These signs appear in next table behind "r".

Table 5. Correlation coefficients values between chemical datas and land use, and their significances.

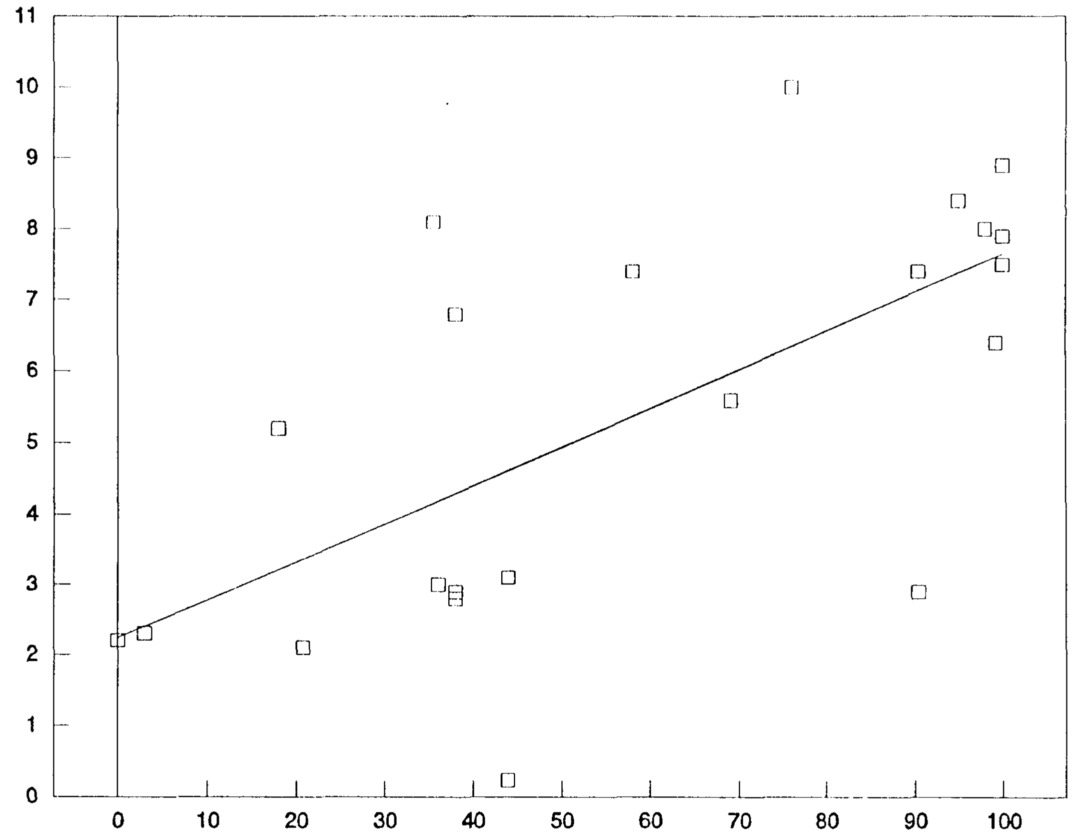
Chem\land use	Paved area	Nature	Cultivation
Acid	- 0.269 NS	0.015 NS	0.130 NS
Aff1	0.067 NS	- 0.508 S	0.521 S
Alka	- 0.157 NS	- 0.036 NS	0.125 NS
Bica	- 0.201 NS	- 0.119 NS	0.241 NS
Ca1W	- 0.306 NS	- 0.361 NS	0.563 HS
Cd2W	0.208 NS	- 0.124 NS	0.023 NS
Cl3	- 0.292 NS	- 0.189 NS	0.367 NS
K20	- 0.273 NS	- 0.392 NS	0.579 HS
K25	- 0.273 NS	- 0.372 NS	0.558 HS
Kj3	0.149 NS	- 0.237 NS	0.178 NS
KW	0.086 NS	- 0.252 NS	0.230 NS
Mg1W	- 0.149 NS	- 0.088 NS	0.178 NS
NaW	0.069 NS	- 0.239 NS	0.225 NS
NH3	- 0.129 NS	0.067 NS	- 0.004 NS
NH32	- 0.146 NS	- 0.013 NS	0.094 NS
NH4N	0.109 NS	- 0.185 NS	0.143 NS
Ni2W	0.111 NS	- 0.139 NS	0.092 NS
NO23	- 0.192 NS	- 0.484 S	0.636 HS
NO2N	- 0.135 NS	- 0.262 NS	0.362 NS
NO3N	- 0.192 NS	- 0.484 S	0.636 HS
O2V	0.034 NS	0.656 VHS	- 0.739 VHS
O2VP	0.025 NS	0.646 HS	- 0.723 VHS
OFOS	0.154 NS	- 0.385 NS	0.339 NS
pH	- 0.243 NS	- 0.079 NS	0.220 NS
pH.v	- 0.148 NS	0.017 NS	0.062 NS
SO4	- 0.063 NS	- 0.159 NS	0.209 NS
Temw	0.057 NS	- 0.107 NS	0.087 NS
Tfos	- 0.003 NS	- 0.535 S	0.589 HS
TotN	- 0.175 NS	- 0.496 S	0.640 HS
Zn2W	0.394 NS	- 0.219 NS	0.026 NS

3.1.2 Interpretation

Thus, all "r values" between paved areas and chemicals can't give us a positive or a negative link between these two groups.
But between nature areas and some chemical datas (O2V, O2VP, Tfos, Affl, TotN, NO3N, NO23) there is a link.
The more nature there is, the more oxygen there is in the water.
On the opposite, the more nature there is the less phosphorus and nitrogen there is.
Similarly, there is a more or less relation between cultivated area and presence (TotN, N03N, NO23, Tfos, K20, Ca1W, K25, Affl) or not (02V, O2VP) of some elements in the water. For the last case, the negative link is very high.
Except for K20, Ca1W, K25, chemicals which have links with nature and with cultivated area are the same, but with a more and less relation and with always an opposite sign.
Thus, we can reckon that nature and cultivated areas are in opposition.
However, many chemical criteria have no link at all with nature or cultivated area.
With another method, the Principal Component Analysis, we are going to see if we arrive to the same conclusion . And this method will have the advantage to show the springs position and so, to be able to discuss on three criteria : land use, chemical products, and springs.
But before, next graphs (1,2,3) represent some of these interesting positive or negative links given by the linear correlation method.

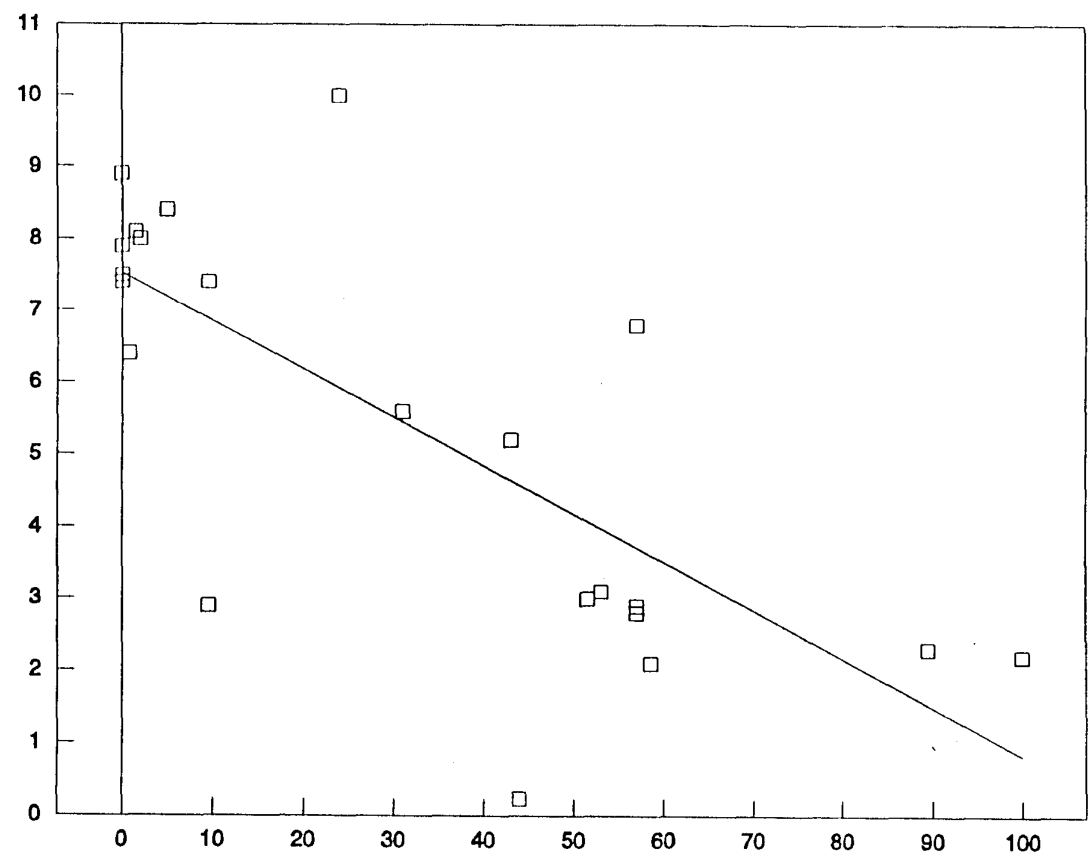
Graph 1. Positive relation between oxygen Y (mg/l) and nature area X (%)

$y=0{,}054055\ x + 2{,}241708$



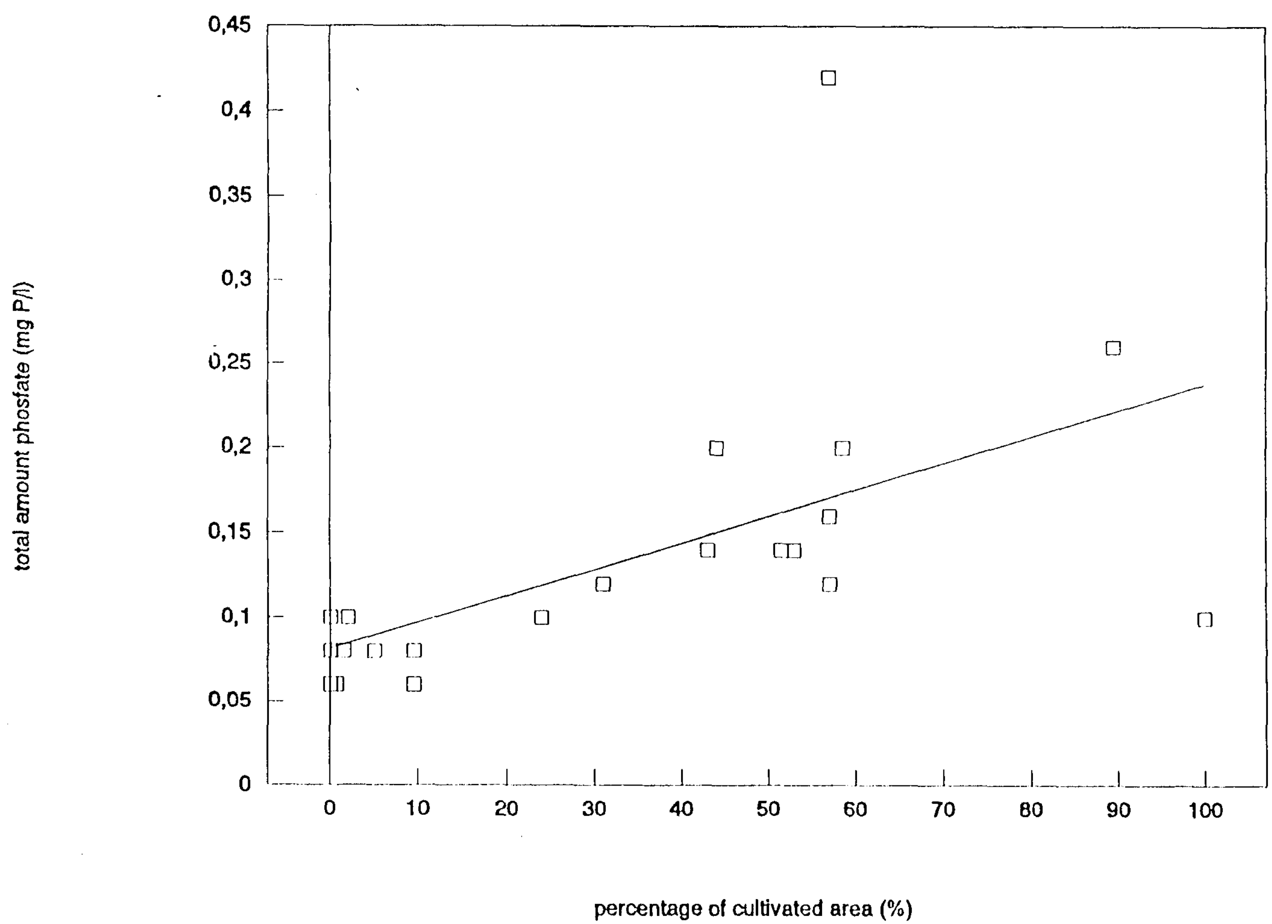
Graph 2. Negative relation between oxygen Y (mg/l) and cultivated area X (%)

$y=-0,06683\ x + 7,522425$



Graph 3. Positive relation between total phosphate Y (mg/l) and cultivated area X (%)

$y=0,001562\ x + 0,081635$



3.2 The multivariate analysis

3.2.1 General points

The aim of data analysis is to study big datas tables, making easier links or differences between some things (for example.springs) and variables which characterize these things.
Factorial methods permit to extract from a table the more important elements, the more interesting tendencies, and to do some simple graphs representations from these phenoma, impossible from the original table. Indeed, if the table contains "n" things and "p" variables, such a graph would contain "n" points in a "p" dimension space (or if the study can be realized indefferently in the other sens, "p"points in a "n" dimension space).
Factorial correspondence analysis and the principal component analysis permit, with a few loss of informations, to realize a synthetic graph on only some axes.

3.2.2 The choice of Principal Component Analysis (PCA)

In our study the variables units are sometimes different and so, an addition of these one isn't possible: the correspondence analysis can't so be used for our datas, and we have to use the Principal Component Analysis.

The "Canoplot" dutch programm has permitted to us to achieve our aim with this method.
We arrive to the two following graphs, where items in the plane are denoted by :

> if the name of the item is printed at the right
< if the name of the item is printed at the left
v if the name of the item is printed under
^ if the name of the item is printed above
. if the name of the item cannot be printed

Land use is always in percentage and the try to use all these datas in square kilometers, and not in %, was done, but didn't change the results. So it is not necessary to present these other graphs.
Figures with this sign "<..." which were used previously in table 4, when the material was not enough precise, have been transformed in some very small values (0,00X), to try to avoid the effect of unknown values.
And all the figures except for pH have been transformed in logarithm to reduce the gaps between the datas.
Results appear in next figures (4 and 5) .

Figure 4. Principal component analysis (Pca)

1. Variables positions

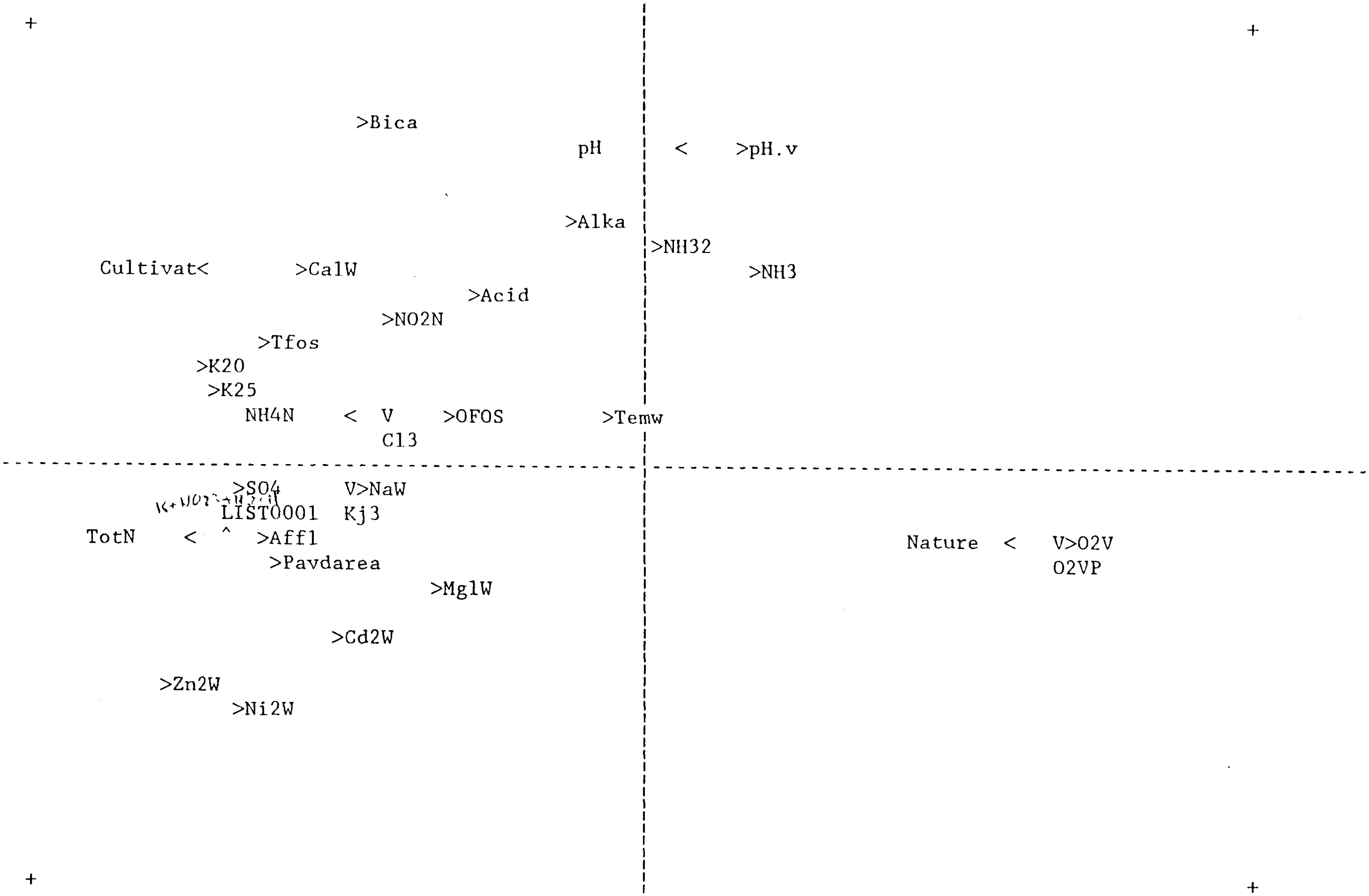
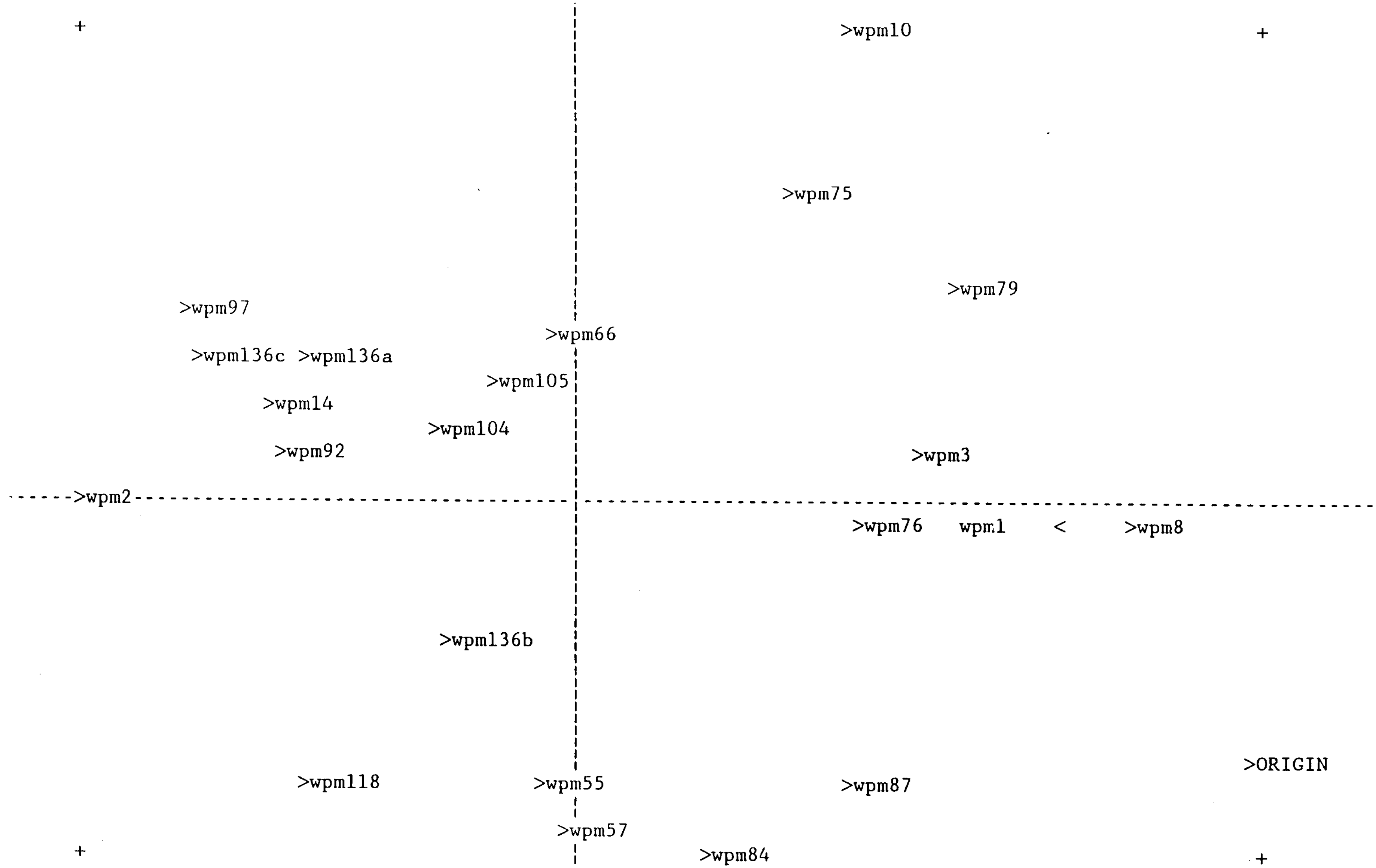


Figure 5. Principal component analysis (Pca)

2. Springs positions



3.2.3 Discussion

First, we can notice that there is a X axe where we retrieve the opposition between nature and cultivated areas. Nature appear very close to the oxygen and far from the elements which characterize the cultivated areas, like we have seen with linear correlation method (TotN, NO3N, NO23, Tfos, K20, Ca1W, K25, Aff1). Nevertheless, this relation between chemicals and cultivated doesn't look really the same than the one we have found before.
This remark can be said also for the relation between chemicals and paved areas which seems stronger for some elements (TotN) than we could expect, previous analysis giving non significant results.
No elements permit us to interprate what means the Y axe.
Some chemical elements look far from each land use criteria and we retrieve there some of the non significant elements like Temw, NH32, NH3.
If we compare the first sheet with the second , we retrieve globally the first classification we have done to characterize springs land use but the intervention of chemicals permit us to gather some springs a bit differently.
These new groups could be the following :

- springs where nature and oxygen dominate : numbers 1, 3, 8,10, 75, 76, 79, 84, 87. These springs were already classified together in our first more simple classification.
- springs where cultivated areas and chemicals in relation with these one dominate : numbers 14, 92, 97, 104, 136(a,c). This bigger analysis permit us to lose number 118 and 136b, and to recover number 105.
- springs depending on chemical criteria which affect paved area : numbers 118 and 136b. It is difficult to give still a meaning when we know that paved areas have no significant relations with chemicals.
- springs more difficult to classify : numbers 2, 55, 57, 66.

Conclusion

This study gives us an idea about relations which exist between land utilization and water quality and shows perfectly obvious links between chemical criteria and cultivated area, and between chemical criteria and nature.

Cultivated area increase the water amount of nitrogen and phosphorus, and conductivity, whereas nature increase the oxygen presence in water. So knowing what we want in water, we have to use land in a certain way.

Paved areas have no significant relation with chemical products and it could be understood because the activity on these areas can be very varied.

The PCA analysis confirms overall the linear correlation method results giving in addition relation with the spring, and the choice of this analysis seems to have been the good one.

Similarly, catchment areas choice lead us to understanding results. Thus, surprises that we could have had, didn't appear such as effect of water coming in our springs by underground and so making difficult the good choice for catchment area.

Unhappily, we didn't have enough chemical datas for our springs about 1950 to be able to compare first the chemical datas in time, and to see if the relation at this period, between land use and chemicals, was or not the same than in the recent years (it should have been).

It will be interesting in some years to do the same study and to compare it to this one.
