Forest management and drinking water: Case studies and recommendations

A Thesis submitted

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Abstract

This Master thesis report has been realised in the context of the Interreg project “Alpeau” between France and Switzerland. Alpeau aims to sustain the protective functions of forest towards drinking water resources and to establish amicable contracts between local authorities responsible for water supply and forest actors.

Cases all over the world where particular forest management has been implemented to protect drinking water resources have been inventoried. The forest management measures applied at these sites and the way they are implemented (land acquisition, regulation, contract) are studied. Broad forest management principles could be highlighted.

These rules are then transposed to French and Swiss sites of Alpeau project. Forest management recommendations are made and propositions of contracts establishment are suggested.

Acknowledgment

I would like to thank all the persons who have helped me during this Master thesis and contributed to the realisation of this report. And especially:

- My supervisor in Austria, **Eduard Hochbichler** (Ao.Univ.Prof.Dipl-Ing.Dr.nat.techn) from Vienna Boku University, for the help he brought to me ;
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- All the water and forest managers I contacted, in several countries, for their collaboration, the time they gave me and the interest they showed in my work ;
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- My tutor in ENGREF (Ecole nationale du génie rural des eaux et forêts – French National Forest School), **Eric Lacombe,** who gave me precious advice to lead this study.

I sincerely appreciated to work on the links between forest management and drinking water quality and to include many different countries in my research area. This topic really interested me a lot and I wish I will be able to follow Alpeau evolutions and results within the next coming years.

This Master thesis work brought me a lot both professionally and personally.

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List of acronyms

BMP : Best management practices
DNR : Department of Natural resources (Etats Unis)
DWSP : Division of Water Supply Protection (Boston)
ENGREF : Ecole nationale du génie rural, des eaux et des forêts (= National French School of Forestry)
FC : forêt communale (= city owned forest)
IWB : Industrielle Werke Basel
ONF : Office national des forêts (=French State Forest Agency)
PPE : Périmètre de protection éloignée (= remote protection zone)
PPI : Périmètre de protection immédiate (= immediate protection zone)
PPR : Périmètre de protection rapprochée (=inner protection zone)
SIEM : Syndicat intercommunal des eaux des Moises
SM3A : Syndicat mixte de l'aménagement de l'Arve et de ses abords
SWM : Satdt Werke München
TMWB : Tokyo Metropoplitan Waterworks Bureau
USDA: United States Department of Agriculture
WAC : Watershed Agricultural Council (New York)

1. Introduction

Having drinking water is the first necessity.

But, whatever their superficial or underground origins, human activities can degrade this resource.

In many places in the world, people noticed that underground water coming from forests has generally a better quality than water coming from agricultural or urban watersheds. Forest produces a cheap and good quality drinking water.

Some local cities try to develop this resource and to understand better the role of forests.

Water policies have created many tools to treat water and punctual pollution sources, but they have less developed support to activities that guarantee good water quality. The regulations to protect drinking water catchment points are necessary but not sufficient. In farm and forest lands, prescriptions are often not well defined, not well understood and not well applied.

Protection zones are not always coherent and prescriptions are fixed without any possibility of evolution. Local stakeholders wonder about the relevance of these constraints, all the more as, sometimes, the identification of forest owners is already a huge difficulty.

On a technical level, the protective functions of forests are recognised as essential by the scientific community but they are not taken into account in water policies.

An interreg project, called « Alpeau », is being elaborated between France and Switzerland. This partnership aims to consolidate and sustain the protective role of forest for drinking water resources. Its objective is to establish amicable contracts between local authorities responsible for water supply and forest actors.

Managers of this project proposed me to work to prepare the Alpeau project, during my master thesis which took place from February to August 2008, in Grenoble (France) at the French National Forest Agency (ONF).

The first objective of my thesis is to realise a prospective study of sites, in the world, that have adopted a particular forest management to protect their drinking water resources. This study concerns both technical forest measures but also modalities to implement them (land acquisition, regulation or contracts). The goal is to make a synthesis of scientific research publications about the interactions between forest and water quality and to learn international experiences in this field to define « good practices » and their associated modalities of implementation.

The second objective is to propose recommendations that can be applied in French and Swiss sites of Alpeau project or to give them ideas that could be implemented later in the scope of this interreg project.

2. Presentation of the Alpeau project and of the legal context

2.1 Presentation of the Alpeau project

The Alpeau project is an interreg program between France and Switzerland, which will start in November 2008.

The ONF is leading this project in France and the University of Neuchâtel is leading the project in Switzerland.

The main objective of the project is to show in order to sustain drinking water resources; it is possible to establish direct amicable contracts between local authorities responsible for water supply and forest owners or managers.

The creation of a common method in France and Switzerland to establish contracts between forest and water managers by the means of this project and to give tools to implement them, is a major innovation and the outcome of several long processes in this alpine region.

A panel of pilot sites has been chosen in France and Switzerland to represent the diversity of the region around Leman Lake, including the Alps and Jura mountains. In each site, both water and forest managers collaborate, which is rather innovative in such projects.

There are three sites in France, all situated in the Alps: Moises-Forchat (Haute Savoie), Arve watershed (Haute Savoie) and Chambéry (Savoie).

There are four sites in Switzerland, situated in the most western part: Côte (Vaud), Broye (Fribourg), Areuse gorges (Neuchâtel) and Lausanne.

Figure1 localises the sites in the Alps.

The Alpeau project will implement actions site by site, but also transversal actions for all sites. Among these transversal actions, a prospective study of sites that are already protecting drinking water with forests is programmed.

My thesis work is totally linked to this action.

2.2 Legal context: current legislation about drinking water protection zones in France and in Switzerland

2.2.1 Legislation in France

Drinking water in France comes from more than 36 000 public catchment points. Their type and number varies in function of regions.

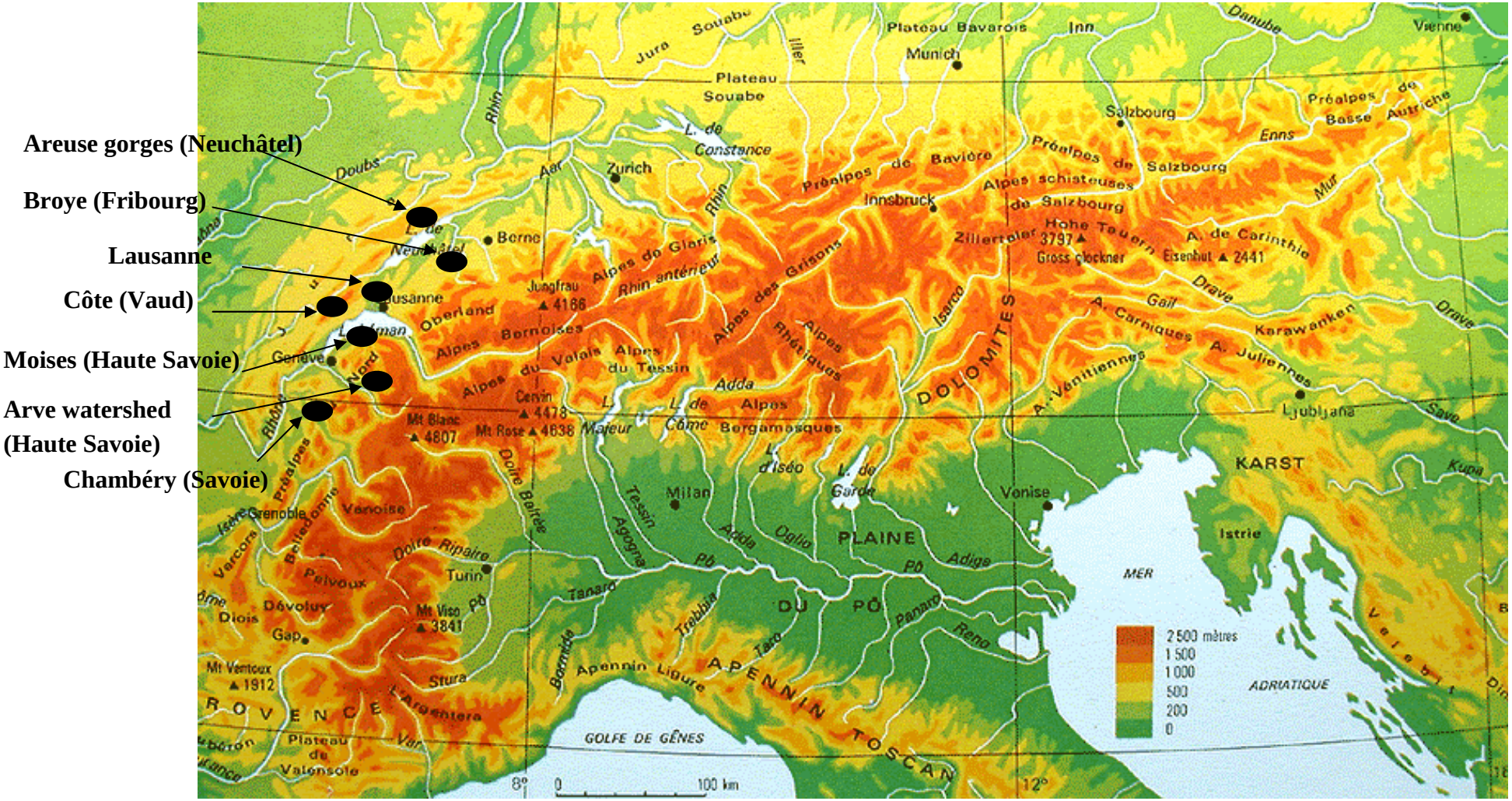
Whatever the catchment type (superficial or underground water), water quality is degraded because of human activities. Water catchment protection is therefore a high necessity.

Laws in 1964 and in 1992 made the protection of each catchment compulsory, with the determination of a protection zone.

But the procedure is long and only half of catchments (70 % of water volume) have a protection zone today.

The protection zones are defined around catchment points after a hydrological study and are validated by the State.

Figure 1: Localisation map of the Alpeau sites
Source of the map: www.alpimages.net/cartes/alpes.php.



Three protection perimeters are defined (figure 2):

- **Immediate protection zone** (« périmètre de protection immédiat » - **PPI**): first level of protection, compulsory. It aims to prevent from direct pollution in the water catchment. This area is usually bought by the water supplier and fenced. No activity is allowed inside, except those linked to the catchment maintenance (picture 1).

Picture 1: Typical PPI situated in forest, deforested and fenced (Masevaux, April 2008)

- **Inner protection zone** (« périmètre de protection rapproché » – **PPR**): this protection area is extended around and upstream the water catchment point. Its shape and area depend on the geologic and topographic context. It can go from 1 to more than 10 ha. It aims to prevent from underground water flow pollution. Human activities are restricted.
- **Remote protection zone** (« périmètre de protection éloigné » - **PPE**): this zone is not compulsory. Its area varies a lot in function of the situation. It corresponds to a restricted watershed. Human activities can be regulated.

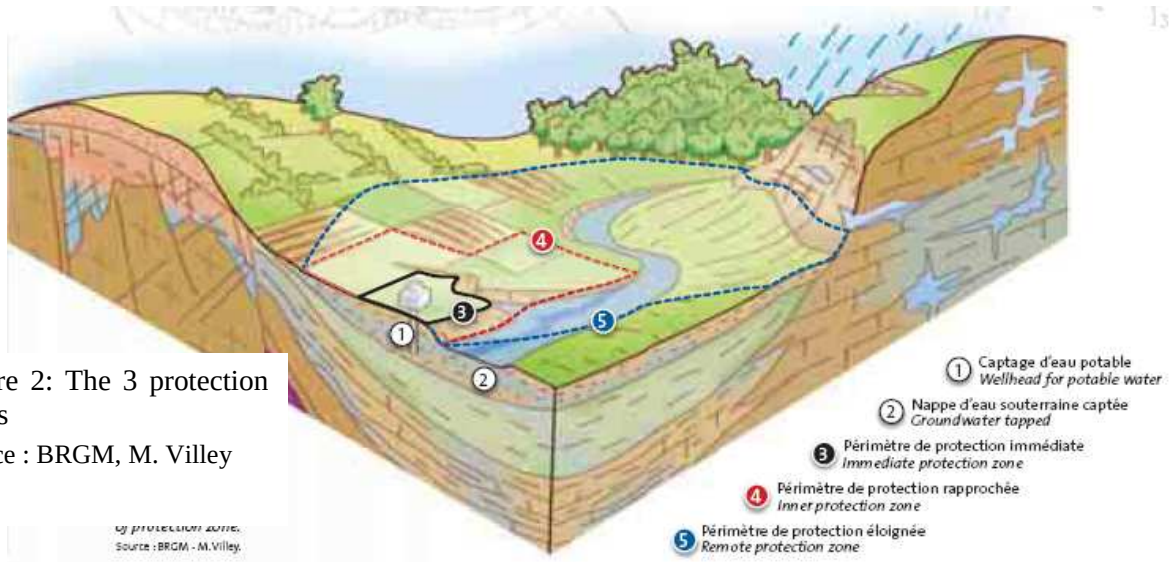


Figure 2: The 3 protection zones

Source : BRGM, M. Villey

2.2.2 Legislation in Switzerland

The Swiss legislation presents the same principles.

Three S zones of protection are defined.

- **Zone S1**: Immediate protection zone; it has to prevent from direct pollution; it has to be fenced (except in forest).
- **Zone S2**: Inner protection zone; it has to prevent from liquid pollution or pollutant input (like fuels).
- **Zone S3**: Remote protection zone; this is a buffer zone; it is a protection against dangerous activities or infrastructures.

In karstic environments, all sensitive zones of the watershed can be classified as S1 zones, which can be very huge areas.

The fundamental difference between France and Switzerland legislations is that, in Switzerland, the rules are the same for every catchment. They are defined by the Federal State. In France, the regulations are adapted to every catchment. They can differ a lot in function of the context but also be very incoherent.

3. Objectives of the thesis method

3.1 Presentation of the objectives

Two of the main actors of the Alpeau project in France at ONF, Claude Barthelon and Olivier Ferry, proposed to work in order to prepare this project.

As the thesis takes place before the official start of the project, the goal for me was to produce a first explorative study. The concrete objectives given were:

- Realise a case inventory where a particular forest management has been implemented towards drinking water protection purposes.
- Analyse these sites/cases to establish a typology of the different forest management methods that protect water resources, and identify the best ones.
- Give recommendations of forest management for two or three sites of the Alpeau project, according to the previous typology. The goal is also to create a dialog with the Alpeau partners of the site: local administration in charge of water resource, foresters…

The schedule initially expected to follow was:

- bibliographic study, taking contacts: 1 month;
- data collection, field trips: 3 months;
- analysis and final report writing: 2 months.

3.2 Presentation of the actual employed procedure

Different steps have been followed during the thesis work. Some of them have been slightly modified compared to this previous frame. The complete analysis of all the Alpeau sites (and not just two or three of them) took more time.

Scientific literature was first gathered to make a bibliographic study to know better the interactions between forest and drinking water.

Cases have been searched, all over the world, where forest is specifically managed to protect drinking water resources. This study concerned both the particular forest management measures and the type of action used to implement them (land acquisition, contracts with owners…). The data collected helped me to highlight general forest management and implementation principles.

The third step of the thesis work has been to study the main characteristics of the French and Swiss Alpeau sites. The ultimate goal was to give recommendations or to bring ideas that could be implemented during the Alpeau project.

Finally, as a last step, a critical discussion of the work has been made, to suggest potential improvements.

The structure of this report follows the same chronological articulation.

4. Methods and data collection

4.1 Scientific context

I first collected information to point out the main scientific results about the interactions between forest management and drinking water.

I tried to gather as much as possible literature about this topic and to find scientific papers from many different countries. I found scientific journals and publications in libraries, through the Internet, and by contacts I had with researchers.

The synthesis of this bibliographic study can be found in paragraph 5.1.

4.2 Case studies

4.2.1 Site inventory all over the world

One of the main objectives of my thesis is to inventory and to study cases all over the world where forest is specifically managed to protect drinking water resources.

Cases have been found on the Internet and in scientific reports that quoted some examples. When I had the information that one site had implemented particular forest management concept and measures to protect its watershed, I looked on websites, contacted managers, asked for information. Sometimes they knew about another similar site, and so on.

This step of my thesis work was pretty long and laborious, but very interesting. A wide majority of water or forest managers I contacted were very interested in my work and are waiting for the final results. They also pointed out that they were lacking of exchanges of experience between sites.

I mainly found sites in Europe and in North America (and one ine Japan). I could only gather sufficient information for these sites. I really regret I did not have enough time to search more in Asia, Africa, Oceania and South America. I found some interesting sites in these continents but I could not have, in time, any contact there that could tell me more about forest management.

My case studies is made of these 12 sites:

- in France: Vittel, St Etienne, Masevaux;
- in Germany: Munich, Hanover;
- in Switzerland: Basel, Winterthur;
- in Austria: Vienna;
- in the USA: Boston, New York, Baltimore;
- in Japan: Tokyo.

4.2.2 Procedure to identify the most important case studies

I compared the 12 sites with the first information I could collect for each of them (appendix 1), according to different criteria.

- <u>Presentation of the criteria</u>

The comparison criteria are:

- type of catchment: catchment of deep water or surface water, stream catchment;

- number of m^3 of "produced" water/day, with corresponding number of people supplied;
- area of the total watershed;
- area of the protected zone of the watershed;

Usually, only one information concerning the area is known (either the total area, or the area of the protected); the ultimate goal is to know both, if possible.

- percentage of forest cover over the watershed;
- type of action: land acquisition, contracts with owners, scientific research, public education, payment of environmental services;
- Peculiarities of forest management over the watershed: species composition, silvicultural treatment, restrictions of harvesting operations, regulation of the use of chemicals…

With the first information received, the sites have been graded for each of these criteria in order to rank them. The goal is to point out the most interesting ones to study in priority.

- <u>Weight given to the criteria</u>

It is difficult, as a first approach, to give more importance to one criterion than to another.

However, 2 criteria, the number of m^3 and the area of the watershed (either the total area, either the protected zone area), give more or less the same information about the size of the watershed. Therefore, in order not to give more importance to large sites and, as a consequence, bias the grading, these 2 criteria will be given a weight of 0,5 and all the other criteria a weight of 1. As a result, to this "global size criterion" will be attributed a weight of 1, like to the other criteria.

- <u>Explanation of the grading</u>

Each criterion has a grade out of 4. 1/4 is the lowest grade, 4/4 is the highest. The thresholds are subjectively fixed in order to have a balanced distribution of the grades among sites.

For each site, all the grades are summed up to give a global "grade of interest".

Below is following the explanation to grade the criteria:

- **Type of catchment**: the shallow catchments or catchments in karstic areas have a high grade, because they are very sensitive to forest management and pollution. Catchments of deep water receive a lower grade.
- **Number of m^3**: the more water, the higher grade.

1/4: Number of m^3 < 50, 000

2/4: Number of m^3 between 50, 00 and 200, 000

3/4: Number of m^3 between 200, 000 and 1 million

4/4: Number of m^3 > 1 million

- **Area of the watershed**: the larger area, the higher grade.

1/4: area < 10, 000 ha

2/4: are between 10, 000 and 50, 000 ha

3/4: area between 50, 000 and 100, 000 ha

4/4: area > 100, 000 ha

- **Area of the protected zone of the watershed**: the larger area, the higher grade.

1/4: area < 1, 500 ha

2/4: area between 1, 500 and 10, 000 ha

3/4: area between 10, 000 and 50, 000 ha

4/4: area > 50, 000 ha

As only one of these 2 area criteria is known, there is no bias left to calculate the final grade.

- **Percentage of forest cover**: the more forest, the higher grade.

1/4: percentage < 25 %

2/4: percentage between 25 and 50 %

3/4: percentage between 50 and 75 %

4/4: percentage > 75 %

- **Type of action**: the more a site has developed its types of action, the more it receives a high grade. Only land acquisition is graded 1/4. Land acquisition with contracts with farmers receives 2/4. Land acquisition with contracts with farmers and forest owners, and education receives 3/4 to 4/4.
- **Peculiarities of forest management**: the more is done to protect water resources, the higher the grade.

1/4: no particular protection measure

2/4: information/education of foresters, encouragement to have management plans

3/4: different measures about silvicultural treatment (irregular usually), species diversification, harvesting restrictions, restricted use of chemicals, education…

4/4: application of all these measures

- <u>Results</u>

Out of this ranking, the most interesting sites are Baltimore, Vienna, Boston, St Etienne (France), New York, Masevaux (France) and Munich. Therefore, these sites will be the first ones to be studied thoroughly.

- <u>Discussion</u>

Some critics can be formulated concerning the employed method:

- Some criteria are not filled (because of lack of information) and therefore the final grade these sites receive is not significant.
- Data is sometimes very uncertain for a few sites; as a consequence, the final grade is also very uncertain.
- The attribution of weights and thresholds for the grading is debatable.
- The case of the site of Basel is particularly penalised by this method, because it is very different from the other ones and therefore it does not fit to the criteria. This site will be therefore studied with attention, despite of its low final grade.

I thought of making a more rigorous analysis, like a multi-criteria analysis. But I abandoned this idea because of the too small sample (only 12 sites) and because the criteria did not fit to every site (case of Basel, for example). Therefore, a more complicated analysis would certainly not have showed more interesting results.

Here, my objective was only to highlight the main characteristics of the sites and point out the most interesting ones, to know which one study in detail would be in priority. I studied each of them afterwards anyways.

4.2.3 Construction of a questionnaire

This questionnaire is available in appendix 2.

Briefly, the main asked points are:

- **Presentation of the situation :** area of the total watershed, area of the protected area of the watershed, percentage of forest cover over the watershed, number of people relying on drinking water from this watershed, number of m^3, price of water;
- **Type of action :** scientific research, land acquisition, contracts with forest owners/farmers, regulations, information of the public, education … ;
- **Management implemented for the protection of drinking water :** *particularities of the forest management over all the watershed area (*tree species composition, silvicultural treatment, harvested volume per cut, regulation/restrictions for harvesting, use of chemical products/ pesticides…), *particularities of the forest management just around the water catchments points (above the water pipes), forest road network (*density, particular measures to prevent erosion processes or surface water streaming), *hunting and recreation management, pasture land or agricultural land management ;*
- **Forest situation :** *forest characteristics (*geologic situation, main types of soils, topographic situation, natural forest communities, actual situation), *forest management* (actual management, articulation between forest management plans and watershed management plan), *ownership* (percentage of public or private owners) ;
- **Relationships between the actors / stakeholders :** relationships with private forest owners, problems or conflicts, others actors/ stakeholders, relationships with research organisms ;
- **Costs :** estimation of the cost (or extra-cost) linked to drinking water objective in forest management, how it is financed ;
- **Evaluation of water quality and of the action plan :** monitoring before/after implementation of the watershed action plan, further water treatment, global evaluation of the action plan, improvements in the future ;
- **References.**

4.2.4 Data collection

I filled in this questionnaire firstly for the most interesting sites identified before, to give them more time.

The data came from management plans and other documents I could find on the Internet and from mail interviews I had with the managers.

For some sites, I could not get all the information I wanted because the managers could not or did not want to answer all my questions.

I also had the great opportunity to visit the sites in France (St Etienne, Vittel and Masevaux), Munich and Vienna. The direct interviews with the managers and field trips I could make there were very fruitful and rich for my study.

All the filled questionnaire forms are shown in appendix 3.

4.3 Application to Apleau sites

The second objective of my thesis is to use all the collected information to give recommendations to Alpeau sites.

The first step has been to collect data on French and Swiss Alpeau sites. I used for this a similar questionnaire to the one from the previous inventory (appendix 5: questionnaire for Alpeau sites).

The different asked points are:

- Presentation of the situation : type and number of catchment points, watershed area, protected zone area, estimation of forest cover, number of people supplied with water, number of m^3/day, price of water ;
- Actual water supply system : actors, water treatment, protection measures around catchment points, quantity and quality of water, encountered problems ;
- Actual situation of the forest : forest sites, management in public and private forest, ownership, forest road, hunting, tourism, pasture land ;
- Relationships between actors : between forest and water managers, with private owners, problems or conflicts, other relationships ;
- Expectations of Alpeau site managers: interest in this project, objectives…

To obtain this information, I went to each site to meet managers and see the situation. The descriptions of the Alpeau sites are in appendix 6.

5. Results

5.1 Scientific context: bibliographic synthesis of the interactions between forest and drinking water

5.1.1 The soil-plant-water system

5.1.1.1 Water fluxes and infiltration process

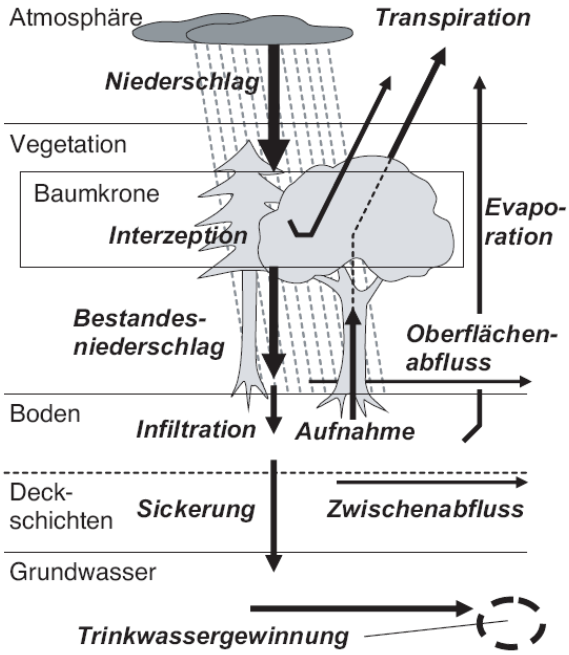
In forests, many water and substance fluxes influence the quantity and the quality of the water that infiltrates in the soil.

The main water fluxes going through the compartments of this system are described on figure 3. Vegetation (mostly leaves and needles from trees) intercept precipitation. Interception varies from 15 to 33 % for broadleaved trees, from 20 to more than 50 % for conifers (COMBE, 2005). The season also influences interception.

This water can then:

- Infiltrate in the soil as through fall or stem flow,
- or move back in the atmosphere by evaporation.

Water storage in the soil depends on the type of the soil (soil type, soil depth, porosity, etc.). The type of vegetation influences the water quantity which will be taken by the roots or directly evaporated in the atmosphere on the soil surface (interception, stem flow, shadow, litter layer). The part of water that is not stored in the soil, or not absorbed by the roots, infiltrates into the aquifer water through superficial soil layers.



Atmosphäre	atmosphere
Niederschlag	precipitation
Baumkrone	canopy
Interzeption	interception
Bestandesniederschlag	throughfall
Oberflächenabfluss	surface runoff
Boden	soil
Aufnahme	uptake
Deckschichten	superficial horizons
Sickerung	percolation
Zwischenabfluss	hypodermic flow
Grundwasser	water table
Trinkwassergewinnung	drinking water catchment

Figure 3: Water fluxes
Source: Hegg,C. et al.(2004). *Wald und Trinkwasser*. WSL

Water coming from several small watersheds infiltrates in the same aquifer water. The transport duration and mixing/transformation processes depend on the type and characteristics of the aquifer (unconsolidated materials, fault, karst).

Figure 4 represents the main substance fluxes determining components concentration in water. Snow and rain contain components from aerosols and gases (humid deposition). Dust and particles also accumulate on vegetation (dry deposition).

Leaves and needles act like a filter to catch these depositions, but the quantity of intercepted pollutants depend a lot on tree architecture (HEGG, 2004). Water that evaporates from leaves is pure, therefore the concentration of the deposited components increases in the water that remains on the tree and reaches the soil. This process is called the purification effect of tree crown (HEGG, 2004).

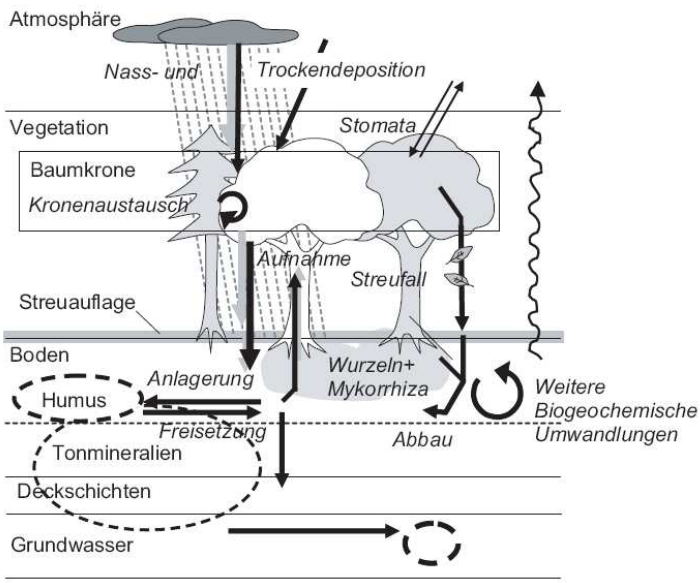


Figure 4: Substances fluxes
Source: Hegg,C. et al.(2004). *Wald und Trinkwasser*. WSL

Atmosphäre	atmosphere
Nass- und Trockendeposition	dry and humid deposition
Baumkrone	canopy
Kronenaustausch	exchanges between tree crowns
Aufnahme	uptake
Streufall	leave fall
Streuauflage	litter layer
Anlagerung	deposition
Freisetzung	releasing
Wurzeln+Mykorrhiza	roots and mychorriza
Abbau	decomposition
Weitere Biogeochemische Umwandlungen	other biogeochemical modifications
Tonmineralien	clay minerals
Deckschichten	superficial horizons
Grundwasser	water table

Forest soil also purifies water. In the underground water of a forest soil, substance concentrations are modified by different processes:

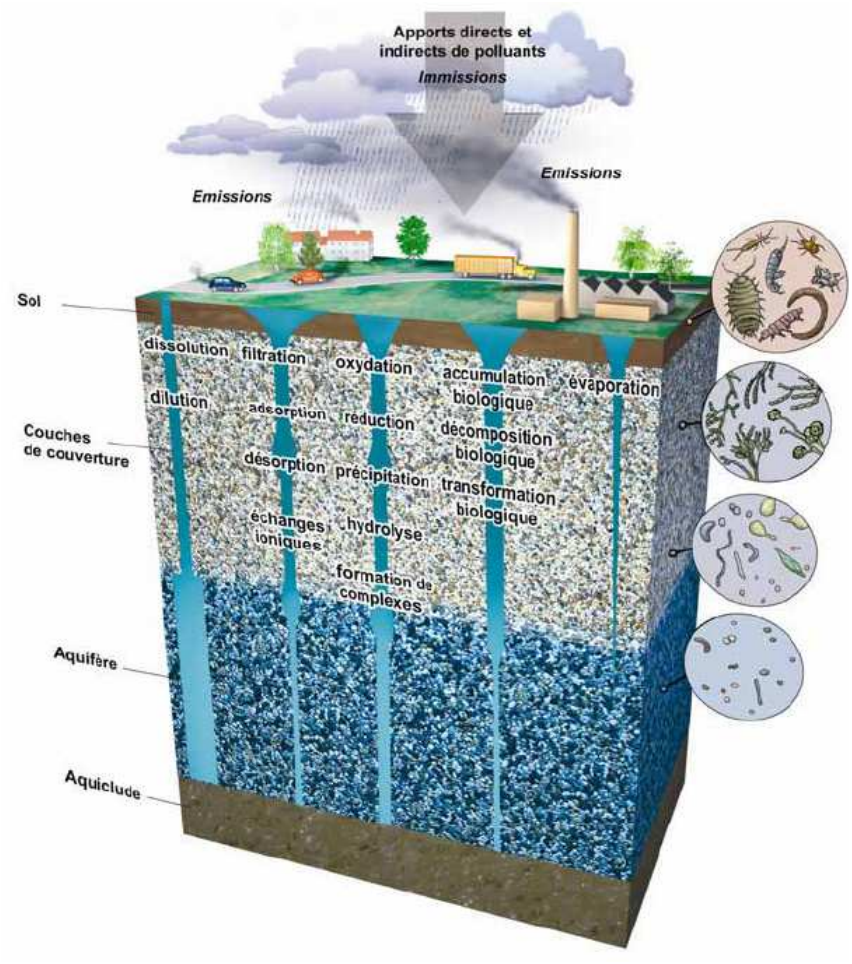
- deposition on humus and clay minerals (ions exchanges),
- uptake of substances by roots,
- fixation in biomass and other biogeochemical transformations.

These transformations are influenced by pH values and Oxygen quantity (redox reactions). Biogeochemical transformations can also solubilise solid substances present in the soil or biomass, this is the process called mobilisation (HEGG, 2004).

Auto-purification phenomena that occur in soils, mainly in horizons A and B, have a very important impact on water quality (fig. 5). Solid particles are filtered and dissolved particles are adsorbed or transformed by biochemical phenomena. Adsorption takes place mainly on clay, oxides and humic substances.

A big part of the pollutants present in infiltration water is retained and degraded in the superficial part of the soil. Auto-purification phenomena decrease in the non saturated zone of the soil. And in the saturated zone, dissolved substances are transported rather quickly on huge distances with

underground water; the decrease of the concentration of these pollutants is then mainly realised by dilution.



sol	soil
couches de couverture	superficial layers
aquifère	aquifer
aquiclude	impermeable rock
emissions	emissions
apports indirects de polluants	indirect input of pollutants
dissolution	dissolution
dilution	dilution
filtration	filtration
adsorption	adsorption
désorption	desorption
échanges ioniques	inonic exchanges
oxydation	oxydation
réduction	reduction
précipitation	precipitation
hydrolyse	hydrolyse
formation de complexes	complex formation
accumulation biologique	biologic accumulation
décomposition biologique	biologic degradation
transformation biologique	biologic transformation
évaporation	Evaporation

Figure 5: Elimination of pollutants in soil and underground. The column width variation corresponds to the relative efficiency of purification phenomena during water infiltration.
Source: Instructions pratiques pour la protection des eaux souterraines (2004). Office fédéral de l'environnement des forêts et du paysage, Berne

5.1.1.2 Factors determining the capacity of a soil to produce good water quality

Several factors have to be taken into account to determine underground water vulnerability for a particular soil.

The DRASTIC method is a well known method used by hydro geologists. Its main principles are described below (SANTE CANADA, 1997).

This method relies on three hypotheses:

- Potential pollution sources occur at the soil surface ;
- Potential pollutants go from the soil surface to the aquifer through infiltration ;
- The nature of potential pollutants is not taken into account.

The seven letters of « DRASTIC » represent the seven factors determining the vulnerability index. These factors are:

- D : depth of water table (5) ;
- R : recharge or infiltration (4);
- A : aquifer media (3) ;
- S : soil media (2) ;
- T : topography (1) ;
- I : impact of vadose zone (volume of soil from 1 meter depth to the water table) (5) ;
- C: conductivity (3).

A weight is associated to each factor (coefficient from 1 to 5 corresponding to the figure given into brackets after each factor just above). The most important factors are the water table depth and the impact of vadose zone, then infiltration, then aquifer media and conductivity, lastly soil media and topography.

A value from 1 to 10 is then attributed to each factor. The lowest value represents the lowest contamination vulnerability. All these values are then multiplied with their associated weight and finally summed up to give the global vulnerability value of a particular hydro geological unit.

The global trends to consider are:

- The deeper the water table, the less vulnerable the site is.
- The more annual infiltration, the more vulnerable the site is.
- Karstic aquifers are the most vulnerable, then sandstone. Metamorphic rocks are the less vulnerable.
- Shallow soils, gravels and sandy soils are very vulnerable. Loams have an average sensitivity. Clays are the less vulnerable.
- The steeper the terrain, the less vulnerable the site is.
- Karstic or basaltic vadose zones are very vulnerable. Then are the sandy vadose zones, sandstone and shale. The less vulnerable ones are made from clay.
- The higher conductivity, the more vulnerable the site is.

5.1.2 Forest roles on underground water

The following results are based on different bibliographic study, in particular from JENNI (2000).

5.1.2.1 Quantitative aspect

Infiltration is higher in forest soil than in any other soil.

Forest influences hydraulic conductivity and, as a result, infiltration capacity of the soil. Under a forest, soils present a very deep and efficient porosity, because of biologic activity and deep roots. In addition, the permanent vegetation cover in forest decreases the risk of crusts formation (due to erosion) and losses by runoff.

Forest soil and its litter layer allow better infiltration and create a high water storage capacity (DUFOUR, 2006). Absorption capacity can be enormous but depends on soil type (BENOIT, 1999). For all these authors, forest soils act like a sponge.

Vegetation limits runoff (COMBES et al., 1995) but favour infiltration.

Forest consumes more water than any other vegetal cover.

Forest intercepts a part from precipitations falling on the ground.

Evapotranspiration of deciduous trees is 20 % higher than coniferous trees (GODI, 2005). In spring transpiration is higher in coniferous stands, but later is higher in deciduous (GODI, 2005). Trees with their deep roots can also better use water stored in soil.

Forest soil structure also limits runoff losses.

5.1.2.2 Qualitative aspect

Forest is the best soil cover in watersheds.

There are very few pollutants inputs in forest ecosystems. Usually, carbon, phosphorus and nitrogen cycles are balanced and there are no or very few losses. Many studies show that nitrogen concentrations are lower in forest soils than in any other soils.

Water quality depends on forest type.

Nitrification is active in aerobic conditions and in soils rich in Ca^{2+}. Under tempered climate, in a deciduous forest, nitrogen absorption is almost equal to annual mineral nitrogen production in mull humus (DUCHAUFOUR, 1997) and there are few losses into underground water.

In acidic or less oxygenated soils (moder humus, coniferous forests), ammonification is the main process. Ammonia is adsorbed on clay and releases H^+ and Al^{3+} ions. As a consequence, the soil is acidified. Coniferous canopy catches more air pollutants, leaching is therefore higher. Moreover, in acidic soils, there is less buffer effect. Forests can therefore receive more nitrogen than they can use it. There is a risk of nitrogen saturation and that nitrogen infiltrates into underground water.

The situation is different in riparian forests where denitrification by micro-organisms plays a very important role (DUFOUR, 2006). Riparian forests could then store more nitrogen than they need it.

Passive and active protection of forests can now be distinguished.

By its presence, forest decreases or prevents from activities that could endanger water quality (no fertiliser or pesticides, no dangerous materials deposition). This is the passive protection of forest.

Active protection encompasses all processes where forest influences directly water quality and quantity. In forest, biochemical cycles are balanced, water infiltrates better, roots structure the soil and therefore water can be better in contact with humus or clay minerals. Forest soils really purify water. But this effect can be affected by air pollution and deposition on canopy.

5.1.3 Forest management influence

5.1.3.1 Influence of a forest cut

- In quantity

Many studies show that, after a forest cut, runoff increases and there is more superficial water flowing in the watershed. But there are few studies concerning underground water flows after a forest cut and results are contradictory (JENNI, 2006).

- In quality

The influence of a forest cut depends on the type of cut. Main cut types studied in the literature are clear cut, strip cut and single tree cut (JENNI, 2006).

Studies show that the presence of natural regeneration has a very huge impact on underground and superficial water quality. This means that the effects of a windstorm or a clear cut depend a lot on the forest site.

Harvesting wood modifies or stops natural biogeochemical cycles and some harvesting methods can increase temporary nutrients leaching. Because of this, no clear cut should be made in zones saturated in nitrogen. After a clear cut, sun radiation coming to the earth is more intense, temperature increases in organic horizons and therefore mineralisation and nitrification increase (DUFOUR, 2006).

Moreover, the increase of water that infiltrates into the soil after a clear cut increases nitrogen leaching during the first years.

This phenomenon has been recorded in many studies. WENGER (2002) found that this effect can happen after a 1 000 m² cut. Progressive cuts that maintain forest cover on the ground limit nitrogen migration in infiltration water. But the amount of nitrogen that is leached depends a lot on forest site and on the nitrogen saturation.

Regeneration decreases nitrogen leaching after a cut (JENNI, 2006). Therefore it is very important to have successful regeneration in forest areas.

Tree branches and cullwood also accumulate nitrogen (DISSMEYER, 2000). But their removal from forest has to be thoroughly examined because other very important nutriments are exported at the same time (Ca^{2+}, Mg^{2+}, etc.).

The area of forested land is also important regarding atmospheric deposition. Deposition decreases from forest border to the middle of the forest. Therefore, small dispersed forests accumulate more pollutants than a huge continuous forest (JENNI, 2006).

Studies in the USA have shown that accelerated nutriment leaching did not occur after heavy cutting, but did follow when herbicides sustained barren conditions after clearcutting. Sediment increases in in-streams exports are minor and short-lived and mostly from roads when best managment practices (BMP) are conscientiously employed (ADAMS et al.;2002).

Another study found that forest practices with the greatest potential for causing erosion and stream sedimentation are road construction, tractor skidding of logs and intensive site preparation (STEDNICK, 2000). Undisturbed forest watersheds usually have erosion rates around 0.57 ton/ha/year. Typical timber harvesting and road construction activities may increase rates to 0.11 until 0.57 ton/ha/year. More intensive site preparation treatments such as slash wondrowing, stump shearing, or roller chopping may increase soil erosion rates up to 11.4 ton/ha/year.

However, many different studies have shown very different results and therefore it is not possible to generalise any of them. Some show that cuts have a huge impact on nitrogen release, some do not show that.

Yet it is possible to summarize that:

Clear cuts induce a sudden and strong nitrogen increase in underground water.

Water quality remains acceptable, except excessive suspended matter loads because of logs extraction.

This influence is limited in the time.

5.1.3.2 Influence of tree species

Infiltration is higher under deciduous trees than under conifers.

In winter time, infiltration is much higher under deciduous trees than under conifers. During the vegetation period, infiltration is higher under young stands and is independent from tree species (JENNI, 2006).

There is less nitrogen losses under deciduous trees than under conifers.

On the one hand, nitrogen cycle is better balanced under deciduous trees:

- Soils are usually less acidic and biologic activity more efficient in deciduous litter ;
- Broadleaved trees have deeper roots and therefore catch more nitrogen.

On the other hand, the « acidic rain » effect is stronger in conifer stands:

- There is more nitrogen deposition on canopy and more nitrogen input in the soil: except alder and acacia trees that fix nitrogen, deciduous trees catch less atmospheric pollutants.
- Soils are more acidic and cannot buffer pollutants inputs. The water saturated zone is reached quicker by pollutants.

To end with, deciduous trees consume less water than conifers. For example, ROETHE et al. (2002) measured that annual percolation fluxes are 223 mm under spruce stands and 329 mm under beach trees in Bavaria. Therefore, for the same quantity of leached nitrogen, the concentration is higher under conifers.

5.1.3.3 Influence of tree age

There is less nitrogen losses under a young growing forest than under an old forest.

In a mature forest stand, nutrient uptake by roots is lowered. In addition, the « acidic rain » effect is more important in mature forest because the canopies are bigger and pollutant interception is higher.

Synthesis

Forest is definitely the best possible cover to protect drinking water catchment areas.

The forest stand age and composition, the type of soil and forest management influence significantly water quality.

In deciduous forests, the nitrogen cycle is well balanced and there are less nitrogen losses. These ecosystems can absorb huge nitrogen quantities. Even natural perturbations (wind throw, fire…) or clear cuts have little impact on underground water quality, except excessive suspended matter loads because of logs extraction.

Forest ecosystems that contain more nitrogen (acidic rain, pure coniferous stands) are more sensitive and forest management is therefore more important.

5.1.4 Basics for "Management concepts": introduction of the Hydrotop model

The city of Vienna has developed with the University of Bodenkultur a new scientific model, the hydrotope concept.

Hydrotopes are defined as areas with (relatively) homogeneous hydrological conditions (GURTZ, 1999; ENGEL, 1996). All different forest communities act in a specific way on a forest-hydrological level, which is caused by the hydrological differences between the specific tree species. As a result of the different actuation of tree species on a forest-hydrological level, the hydrotope system was regarded as appropriate for the stratification task within the headwaters region (KOECK et al., 2007).

The natural forest community was regarded as the most important stratification category of the hydrotope model and was therefore selected as the uppermost stratification level. The uppermost stratification level is an orientation framework, which categorises the headwaters region by creating operational units. In addition, the natural forest community reflects other information layers of the hydrotope system, like soil type, bedrock type (geology) and elevation above sea level (relief parameters). The further advantage of the hydrotope model is that it is possible to define optimal and suboptimal states of each hydrotope.

This model is a management tool to define, in each forest site, which is the ideal stand to optimise the water protection functionality of the forest stands (KOECK et al., 2007a).

5.1.5 Paying forest for its services

5.1.5.1 Different evaluation techniques of forest amenities

Few functions and services offered by forest ecosystems are directly tangible. Their value depends on the social and economic context. They are complex goods that procure a different satisfaction in function of each individual. This satisfaction corresponds to the direct or indirect use of these goods, or to the simple existence of these goods.

The main methods to evaluate forest goods are given in the following table (table 1).

Source : CEMAGREF, Unité de recherche agriculture et forêts méditerranéennes (1992). Usages et fonctions multiples de la forêt méditerranéenne. Guide technique du forestier méditerranéen français, chapter 8

Function	**Main evaluation method**
Recreation Hunting Picking Pasture	Substitution method Marginal productivity method Opportunity cost method
Education Landscape Culture Hydro regulation Soil protection Purification Climate regulation	 Travelcost method Contingent method Hedonist prices method Avoided cost method
Symbolic Scientific Biodiversity	Contingent method Expected productivity method

Table 1: Economic evaluation functions of forest functions

5.1.5.2 Examples of environmental payments services in the world

Here are some examples of environmental payments services taken from IUCN (2006). Establishing payments for watershed services.

- **Sustainable water management in the Catskill and Delaware watersheds, USA**

The Catskill and Delaware watersheds provide New York City's 9 million residents with 90% of their drinking water supply. Historically, these watersheds have supplied high quality water, but in the 1980s concerns about pollution increased. In 1992, the City of New York decided to invest in protecting watersheds rather than new water filtration facilities, which would have cost US$ 6 to 8 billion to build and US$ 300 million annually to operate. The costs of investing in watersheds to maintain and restore natural filtration are much lower. Diverse mechanisms for investment in the watersheds are used. Investment of US$1 to 1.5 billion over 10 years was financed by a 9% tax increase on New York City water bills. In comparison, a new filtration plant would have required a two-fold increase in water bills.

Funds have been used to finance a US$ 60 million trust fund for environmentally sustainable projects in the Catskill watershed. The City has provided US$ 40 million in compensation to cover the additional costs of dairy farmers and foresters who adopted best management practices. Foresters who adopted improved forest management, such as low impact logging, received additional logging permits for new areas. Forest landowners with 20 ha of land or more that agree to commit to a 10-year forest management plan are entitled to an 80% reduction in local property tax. The City is also purchasing development rights for sensitive land near reservoirs, wetlands and rivers at market price. Farmers and forest landowners are able to enter into 10 to 15 year contracts with US Department of Agriculture to remove environmentally sensitive land from production.

- **Securing aquifers – a private sector payment scheme by Nestlé Waters in France**

Vittel (a subsidiary of Nestlé Waters) is the world's largest bottler of natural mineral water. Its most important water sources in France are in heavily-farmed watersheds. Runoff of nutrients and pesticides risked contaminating the aquifers on which the company's business depends. The company determined that purchasing farmland, reforesting sensitive infiltration zones, and financing farmers to build modern facilities and switch to organic farming was in fact more cost effective than building filtration plants. The cost advantages were so significant that participating farmers could be offered extremely profitable terms.

Stakeholders involved:

• *Buyers:* Vittel, a bottler of natural mineral water.

• *Sellers:* Farmers and landowners. In compensation for reduced use of fertilizer – and hence reduced profitability and higher perceived risk – farmers were given contracts by Vittel for up to 30 years.

• *Intermediaries:* The *government* facilitated the deal by providing a small amount of financial aid and a strong legal framework to ensure the enforceability of contracts.

Payment scheme type: Private sector payment scheme. Vittel purchased 1500 ha of farmland for US$ 9 million, paying more than the market price. Usufruct rights were then granted back to the farmers, giving them the legal right to use and derive profit from land owned by Vittel. Farmers receive US$ 230 per hectare annually to manage the land using sustainable practices that ensure high water quality standards.

- **Controlling nitrogen discharges – a cap-and-trade scheme in the USA**

The Clean Water Act in the USA limits the level of nutrients allowable in waterways. To comply with the Clean Water Act, states have developed strategies to keep nutrient discharges below the total maximum daily load allowed under the Act. The Connecticut Nitrogen Exchange Programme is a 'cap-and-trade' scheme for nitrogen discharges through which entities that discharge less than the nitrogen loads allowable (or 'capped') under the Act, can sell (or 'trade') their nitrogen discharge rights to those who exceed their allowances. This creates a financial incentive to diminish nitrogen discharges below allowable limits in order to profit from the sale of those discharge rights – while at the same time the scheme ensures an acceptable cap on total discharges.

- **Saving native salmon – a certification scheme in the Pacific Northwest of the USA**

A successful certification scheme was set up a decade ago to protect the habitat of the Pacific salmon, which is native to the Northwest of the United States. The scheme was established by 'Salmon-Safe', a non-profit organisation. Erosion and runoff from hillside vineyards and farms brought silt into streams, which had reduced the ability of native salmon to spawn and thrive. Salmon-Safe certifies farms and urban land in watersheds in the states of California, Oregon, Idaho and Washington that practice 'fish friendly' management. Salmon-Safe has now certified management of 20,000 hectares of land.

Stakeholders involved:

• *Buyers:* Consumers in the Pacific Northwest who choose "Salmon-Safe" products and pay a premium on top of the normal retail price to support land management that keeps rivers clean and safe for wild salmon.

• *Sellers:* Farmers and winegrowers.

• *Intermediaries:* Salmon-Safe, who oversees the certification scheme and supports the price premium through education and marketing campaigns.

Payment scheme type: Certification scheme. Participating farmers apply ecologically-sustainable agricultural practices that protect water quality in rivers and salmon habitats. These practices include tree planting on stream banks, growing cover crops to reduce runoff, and application of biological control methods for weeds and pests. The extra costs are paid out of the premium that participating growers receive for their products. Marketing of these products, including wine and foods, is assisted by public education and awareness campaigns by the Salmon-Safe organisation.

- **Protecting watersheds – a water protection fund in Quito, Ecuador**

The Water Protection Fund (FONAG) was created in 2000 in response to the pressing need for better management in the watershed that provides Quito's water supply. The fund was created by a local NGO, Fundacion Antisana, and The Nature Conservancy (TNC), after the Ministry of Environment commissioned the development of a management plan for two reserves in the upper watershed. It was designed to run for 80 years, to ensure long-term institutional and political legitimacy. In 2006, the fund's endowment was US$ 3.5 million, but was expected to grow to US$ 7.4 million by 2010.

Stakeholders Involved:

• *Buyers:* FONAG and its contributors.

• *Sellers:* Watershed managers and advocates. Those who undertake reforestation, surveillance of protected areas, sustainable management in agriculture, and development of ecotourism, training, communication and environmental education.

- **Management of watersheds by "Water agencies" in France: a environmental tax system**

France is divided into 6 different watersheds which are, each one, managed by a water agency. These agencies establish pluriannual programs to implement the European framework water directive and to protect water resources.

These agencies are financed by a tax taken on water bills paid by consumers calculated in function the volume they consume. For the next 6 years, these agencies will receive 11.6 billion Euros.

5.2 Case studies of sites where forests are managed to protect drinking water

5.2.1 General characteristics

Table 2 presents the types of action used for each site.

Table 3 gives the general characteristics of each site (type of water catchment, number of m^3/year, watershed area, percentage of forest cover in the watershed, price of water, water treatment).

Table 4 indicates forest management measures (forest site, actual forest situation, management objectives, method and means, particular measures nearby catchment points).

Site	**Land acquisition**		**Contracts with farmers**	**Contracts with foresters**
	past (before 1980)	**current (after 1980)**		
Basel	x			
Baltimore	x		x	x
Boston		x	x	x
Hanover	x			
Masevaux	x			
Munich	x	(x)	x	
New York		x	x	x
St Etienne	x	x		(x)
Tokyo	x		*No contract but strong awareness raising of the public*	
Vienna	x	(x)		
Vittel		x	(x)	
Winterthur	x		(x)	

Table 2: Summary of types of action used in each site

Site	Type of water catchment	Number of m^3/day	Watershed area in ha	Protected area in ha	% of forest	Price of water	Water treatment
Basel	water from the Rhine river is pumped and seeped into a forest to be filtered and pumped again when it arrives in the water table	75, 000		230	100	1.40 CHF/m^3 (supply and sanitation)	chlorination, degassing, coal treatment
Baltimore	catchments of rivers/streams (reservoir)	~ 2, 800, 000	11,5 000		?	?	chlorination and filtration
Boston	catchments of rivers/streams (reservoir)	600, 000		48 000	90	1 $/ m^3 (supply and sanitation)	chlorination
Hanover	110 wells in water table	137, 000	30, 000		50	0.6 €/ m^3 (supply)	Chlorination and filtration when pipes maintenance
Masevaux	10 shallow catchments (3 to 4m) and wells in alluvial water table	700		1, 250	100	2.85 €/ m^3 (supply and sanitation)	Chlorination (and soon neutralisation)
Munich	catchment of surface streams, catchments of shallow water	411, 000		6, 000	~50	1.42 €/ m^3 (supply and sanitation)	none
New York	catchments of rivers/streams (reservoir)	5 millions	414, 100		75	?	?
St Etienne	shallow catchments (1.80 to 2m), filtering soil	29, 000	2, 500	1, 200	100	4.32 €/ m^3 (supply and sanitation)	Chlorination and UV
Tokyo	catchments of rivers/streams (reservoir)	4, 400, 000	48, 000		100	2 €/ m^3 (supply and sanitation)	chlorination and filtration
Vienna	almost all water comes from the catchment of 2 streams, karstic area, spring water	400, 000		60, 000	65	1.2 €/ m^3 (supply and sanitation)	chlorination
Vittel	deep wells, soil sensitive to pollution	Not comunicated	5, 000		11	Mineral water	none
Winterthur	water comes from alluvial water table	23, 000		1, 900	100	?	none

Table 3: Main characteristics about water supply in each site

Site	Forest site characteristics	Actual forest stands	Objectives	Methods	Other measures	Measures near catchment points
Basel	Rhine alluvium, plain, P= 788 mm/year et T= 11.3°C/year	Mixed deciduous forest, uneven-aged	Reached (corresponds to actual forest)	Different harvesting methods (chainsaw, harvester, tractor/skidder)	Biologic oils recommended	Deciduous trees, fence, manual forest work, no wood production
Baltimore	Well drained soils, elevation : 30 to 275 m, P= 1035 mm/year, T=12.8°C/year	Very diverse : deciduous forests and pine plantations	Diverse stands (in species, age and structure) and alluvial forests	Measures against game to favour regeneration and against invasive species, deciduous trees plantation, application and evaluation of BMP		Riparian zones restoration
Boston	Well drained soils, elevation : 161 to 421 m, not steep, P=1178 mm/year	Uneven-aged stands, mainly *Quercus rubra* and *Pinus strobus* (natural species)	Mixed species stands, uneven-aged	Regeneration by small openings, measures against invasive species	Particular measures for road log landings, biologic oils recommended	Limited harvest, opening < 0,2 ha, cut < 50 % of volume
Hanover	podzols and sandy gleys, plain, P=712 mm/y, T=9.9°C/y	Stands resulting from pine plantations	Mixed stand deciduous-conifer, continuous forest cover	Beech and red oak plantation	no pesticide	Fence around catchment points
Masevaux	Rich brown soils, elevation : 395 to 1190, steep, P= 1400 mm/y, T=8°C/an, 620 m alt → beech-fir forest	Beech/ beech-fir stands, continuous forest cover (long regeneration period), some stands recently destroyed by wind throw	High forest (but long regeneration period) of beach, fir and other species	Generalise cable yarding in protection zone	Exchange of GIS data between water and forest managers, biologic oils compulsory	No tree around catchment points
Munich	Deep and rich soils, not steep, elevation : 600 to 900m, P=1500 mm/y → beech-fir forest and deciduous trees in valleys	Stands resulting from spruce plantations	Mixed stand deciduous-conifer, continuous forest cover)	Harvest in winter (chainsaw : harvester, tractor), 50 to 100 m^3/ha removed per cut, 5 year rotation (to reduce volume)	Biologic oils, no pesticide, low pressure tyres	No tree around catchment points (superficial pipes)

Table 4-a: Forest management in each site

Site	Forest site characteristics	Actual forest stands	Objectives	Means	Other measures	Measures near catchment points
New York	Acidic soils, steep	Diverse deciduous stands, different ages	No management objective except keeping forests in the long term	No particular prescriptions	Management plans creation, development of BMP (erosion, river crossing, riparian zones), forest owners education	No access, adapted « soft » management
St Etienne	Deep brown soils, elevation : 800 to 1250 m, P=1000 mm/y → beech-fir	Fir forest, uneven-aged	Fir-beech forest, uneven-aged	Favour deciduous trees regeneration	Biologic oils, no pesticide	No tree around catchment points (superficial pipes), no fence, no machines crossing above pipes
Tokyo	Elevation from 500 to 21000 m, brown soils, T= 8.5 to 13.1°C, P= 1552 to 1684 mm	70% of « natural » forests (deciduous and conifers) and 30% of conifer plantations	Conserve « natural » forests, 44% of plantations have to become « natural » and 56% of plantations have to become a high forest	No management in « natural » forests and 44% plantation, forest cuts in 56% plantations	no pesticide, protection against game for regeneration	?
Vienna	karst, elevation : 470 to 2277 m, rendzine-leptosols and chromic cambisols, P=614 to 1071 mm/y et T=6.7 to 9.4°C /y	Stands resulting from spruce plantations and also natural mixed stands	Mixed forest defined by hydrotope model, uneven-aged	Deciduous tree regeneration under spruce by small openings, cable yarding	Biologic oils, no pesticide	Very soft management around dolines, best management practices to optimise the water protection functionality of the forest stands
Vittel	elevation : 330 to 450 m, not steep, P=923 mm/y, T=8.7°C/y	Deciduous stands (oak), mostly high forest	Uneven-aged forest stands, oak and other deciduous	Small openings, harvest very careful with soil (sometimes with horses)	no pesticide, machines with double tank wall	Very deep wells → no particular measures
Winterthur	?	63% of conifers, 37% of deciduous	Adapted species, uneven-aged forest	Riparian forest restoration, silviculture « close to nature »	Biologic oils	Riparian zones restoration

Table 4-b: Forest management in each site

5.2.2 Study of the different types of action

The methods to implement forest management measures are really diverse. Land acquisition and contracts with farmers or foresters are largely used.

5.2.2.1 Land acquisition

In Europe, land acquisition is the main tool and many cities have bought land in their watershed since the end of the 19th century, understanding the importance of this zone to protect drinking water. Today, some cities still buy, at the market price or higher, forest lands situated in the protection zones, or outside, to exchange them later.

In the USA, the issue of protecting water resources is more recent and cities usually do not own large forests. These towns try actively to buy land in their watershed, usually at the market price to voluntary forest owners. For example, New York City has bought 24, 000 ha of forest for 10 years, after having solicited the purchase of 144, 000 ha.

But for most cities, land acquisition is not enough and they also establish contracts with private owners.

5.2.2.2 Establishing contracts with farmers

On many sites forest and farmland are both present within watersheds or protection zones.
Farming activities are often a source of pollution (nitrates, pesticides) and therefore local authorities have established contracts with them, both in Europe and in the USA.

Munich case is well known.
Strong pollutions in nitrates and pesticides happened in the 80s and 90s. The city of Munich decided to implement an organic farming program with 3 organic associations (Bioland, Naturland and Demeter) within the protection zone. Farmers have to join one of these associations and respect organic farming rules. In exchange, they receive financial compensation from Munich city. Farmers receive around 500 €/ha/year when they accept this contract.
Today, more than 100 farmers have signed this contract. This represents 2, 300 ha (85% of farmers), of which 1, 800 ha are situated in the protection zone.
Thanks to these measures, today no nitrates can be found anymore in Munich water.

In Vittel (France), the situation is different.
Nestlé started since 1987 to buy land from farmers, because of problems of nitrate pollution in the 70s and 80s. The farm lands have then been rented for free to the farmers (tenant farming of 18 to 30 years) with rules to respect concerning water protection.
It is interesting to see the difference: Munich managed to establish contracts; Nestlé in Vittel had to acquire the land. Finding a simple explanation is not easy. The cultures of the two populations are different and the financial consequences were not the same.

In the USA, cities establish very easily contracts with farmers and foresters. But the aim is mainly to keep a farming or forest activity on the ground, and not to make owners adopt a particular management. These contracts are detailed in the next paragraphs.

5.2.2.3 Contracts with foresters

It is possible to find contracts with forest owners only in the USA. These contracts are based on interesting principles totally unknown in Europe.
For information, it is possible to cite a recent initiative in Soleure Canton (Switzerland) which aims to give financial compensation to the restrictions imposed by water protection laws in forest.

5.2.2.3.1 Rural land protection programs in the USA

Different programs have been implemented in the USA to protect sensitive rural lands (farmlands and forests). They are listed by an organism called American Farmland Trust and they are adapted State by State. Their implementation is very flexible and can be very different from one county to another. For example, in Maryland, the Rural Legacy Program implements these contracts.

- **Basic principle of the contracts : the concept of development rights**

These programs give an alternative to farmers and foresters to selling their land to developers by the possibility of selling only the development rights of their land and therefore to continue with their farming or forest activities.

The development rights are distinct from the residual farm /forest value. An owner can sell the developments rights of his/her land, but he/she remains the owner.

Concretely, owners keep the right to manage and harvest their forest/farm but they cannot build new infrastructures there (building, road…)

When they sell the developments rights, owners have to keep their land in the present state.

If it is forest land, they have to respect BMPs to limit erosion. If it is farm land, they have to follow a « nutrient management plan ».

These programs identify different sensitive zones that are very important to protect. They concern only lands that are situated in these sensitive zones.

To be eligible to sell the developments rights, the land must:

- be situated in a rural conservation zone ;
- have a minimum area of 20 ha ;
- have a soil conservation plan.

- **Conserve rural areas : some examples of programs**

- Transferable Development Rights (TDR)

Transfer of development rights programs allows landowners to transfer the right to develop one parcel of land to a different parcel of land. Generally established through local zoning ordinances, TDR programs can protect farmland by shifting development from agricultural areas to areas planned for growth. When the development rights are transferred from a piece of property, the land is typically restricted with a permanent agricultural conservation easement. Buying development rights generally allows landowners to build at a higher density than ordinarily permitted by the base zoning in designated receiving areas.

Two types of TDR exist: land developer can buy directly development rights to farmers/foresters, or the market can be indirect (local authorities buy development rights to farmers/foresters and they sell them after to land developers).

- Conservation easements purchase

Agricultural conservation easements are designed specifically to protect farmland. Landowners who sell easements retain the right to use their land for farming, ranching and other purposes that do not

interfere with or reduce agricultural viability. They continue to hold title to their properties and may restrict public access, sell, give or transfer their property, as they whish. Conservation easements limit land to specific uses and thus protect it from development. These voluntary legal agreements are created between private landowners (grantors) and qualified land trusts, conservation organizations or government agencies (grantees). Grantors can receive federal tax benefits as a result of donating easements. Grantees are responsible for monitoring the land and enforcing the terms of the easements.

- Instalment purchase agreement

An instalment purchase agreement (IPA) is an innovative payment plan offered by a handful of jurisdictions with Purchase of Agricultural Conservation Easement (PACE) programs. IPAs spread out payments so that landowners receive semi-annual, tax-exempt interest over a term of years (typically 20 to 30). The principal is due at the end of the contract term. Landowners also can sell or securitize IPA contracts at any point to realize the outstanding principal.

- Tax credit exchange : example of Colorado

Colorado has developed a program where land owners can sell their development rights as « conservation easements ». Land owners do not receive the money of the sale in one time, but as tax credits.

The credit can be used to pay the taxes in lieu of cash. If the credit is applied to the owner's own state income tax, the taxes will be reduced by the amount of the Credit.

If the credit exceeds the taxes owed, the credit can be carried forward and used over the next 20 years. After twenty years, any unused portion of the credit expires.

Case study: Facilitated credit transfer transaction

John Brown has a $230,000 Colorado Conservation Tax Credit that exceeds his taxes due. Rather than using the Credit over 20 years, he wishes transfer it and immediately receive cash that he can reinvest in his ranching operation. John is unable to find a buyer for the Credit, so he contacts a tax credit facilitator.

John's Credit is matched with a purchaser who needs the Credit to offset his or her Colorado state income tax. Credit prices are market driven, but purchasers have recently saved approximately 13% on their state income taxes.

Sellers like John have typically received approximately 82% of the value of his Credit. The remaining 5% of the value of the Credit funds the transaction costs of the facilitator (Conservation resource Center (2007): Tax credit exchange).

- **Change owners practices : example of the Florida panther protection**

Another original example deals with the protection of the Florida panther. This endemic animal was threatened of extinction, partly because of the degradation of its habitat. After many failures to convince farmers to change their practices to respect Florida panther habitat, an association suggested to farmers to gather and to define themselves which measures will make them change their practices.
Landowners created a program of restoration and conservation of the panther habitat, by using different types of contracts. Every farm land has to have a global management plan, approved by authorities. This plan defines which measures have to be taken in each land, according to the importance of the land ecological characteristics for the panther.
Three levels of action, corresponding to three levels of remuneration, have been set (table 5).

	Action	Corresponding remuneration
1	Land owners lease their non-agricultural development rights (they can go on with farming activities but they cannot build infrastructures).	Income and estate tax credit (during 25 year = duration of the lease)
2	Land owners lease their agricultural development rights if experts estimate that some farming activities are not compatible with habitat panther protection.	Agricultural development rights value determination - The difference between the value of land in its most restrictive agricultural use and the value of land sold on the open market fully permitted for the most intensive agricultural use allowable. Agricultural development rights compensation - the landowners would be compensated for the lease of agricultural development rights in the form of income and estate tax credits, cash or other non-cash methods, agreeable to by both parties.
3	Owners have to restore panther habitat if experts think it is necessary.	Landowners are compensated for the amount of money spent to restore the habitat

Table 5: Different levels of action and financial compensation to save Florida panther habitat

5.2.2.3.2 A contract experience in Switzerland

In Soleure canton, the research office Kaufmann tries to implement a system of remuneration to compensate for restrictions management imposed to forest owners in water protection zones.
Forest produces good quality water at a low price. But regulations forbid some activities in forested protection zones (no pesticides, precautions concerning fuels and lubricants, no intensive forest harvesting, restriction about circulation on forest roads, no nursery creation, no soil extraction). Forest owners have therefore to transport wood out of the forest very quickly. This can induce over costs because machines are not allowed to stay during the night in water protection zones.
The State does not have to compensate for these restrictions.

The research office had the idea to create, in association with private forest owners and the Soleure canton, a contract-form that could establish rules of remuneration between forest owners and local water managers. Both parts have to agree to sign this contract.
The price scale criteria for the compensation rely on several information linked to the forest site productivity, the slope of the terrain (consequences on harvesting costs), the accessibility (consequences on storing, transport), the ground obstruction (vegetation, rocks), the percentage of conifers, the distance until the limit of the protection zone (Amt für Umwelt, 2006).

The distribution of points in function of the criteria is explained in table 6.

Criteria	Points				
Productivity (m^3/ha)	> 12	10-11.9	8-9.9	6-7.9	< 6
	8	6	4	2	1
Slope	< 30 %	30-60 %	> 60 %		
	2	1	_		
Accessibility (ml/ha of forest roads)	> 100	70-100	<70		
	2	1	_		
Ground obstruction	low	average	high		
	2	1	_		
% of conifers	> 60 %	30- 60 %	< 30 %		
	6	4	2		
Distance to the limit	> 400 m	200- 400 m	< 200 m		
	8	4	2		

Table 6: Distribution of points between different criteria – Remuneration method of Kaufmann office
Source: Amt für Umwelt (2006). Merkblatt, Entschädigung von Grundwasserschutzzonen im Wald

The points given for each criterion are summed up. In function of the total number of points, a financial compensation rate is suggested (table 7). This remuneration differs in function of the protection zone (S2 or S3; S1 is not considered because the restrictions are too high and it is better for owners to sell their land).

Total of points	Remuneration in Swiss Francs by ha/year	
	Zone S2	**Zone S3**
25-28	130	70
21-24	110	60
17-20	90	50
13-16	70	40
9-12	50	25
5-8	30	10

Table 7: Remuneration rate corresponding to the total of points - Remuneration method of Kaufmann office
Source: Amt für Umwelt (2006). Merkblatt, Entschädigung von Grundwasserschutzzonen im Wald

In S2 zone (inner protection zone) 30 to 130 CHF/ha/year could be given to owners (20 to 80 €/ha/year).

Up to now, no contract based on the method has been signed between local authority and forest owners.

The research office points out that there are financial compensations for farmers but not for foresters, and this should change. They recommend to insist and to ask to water managers to give remuneration to foresters, ans this because it is not sure that forest will always produce pure water « for free » (KAUFMANN, 2008).

5.2.2.3.3 « Remunerate » public forest: examples of Saint-Etienne and Winterthur

In Saint-Etienne (France), the private company that delivers water has signed a contract (provision of service) with the French national forest agency (ONF) for 22, 000 €/year. In exchange, ONF has to do a regular surveillance of harvesting activities nearby water pipes and of recreation, program the maintenance work of the pipes (master building), deforest just above the water pipes. Other services can be done by ONF under punctual estimate.
This provision of service is not equivalent to a contract where ONF would be remunerated for its protective forest management (SABOT, 2008).

In Switzerland, the city of Winterthur manages and delivers water by communal services. In the water protection zone, wood harvesting is restricted by some precautions, which induces an over cost for forest communal services. Since 2002, these over costs are not attributed anymore to forest but to the product « protection of nature, landscape and water » (HAAGMANS, 2003).
A new step is made so that wood production does not take « for free » over costs from other forest services.

5.2.3 Analysis of forest management measures

5.2.3.1 Very strong similarities

There is rather a strong consensus about the forest management measures to apply to protect drinking water resources among the sites.

- **Continuous forest cover**

A wide majority of sites have adopted uneven-aged forest treatment (strip, group or single tree selection system), which guarantees continuous forest cover.

Managers insist on the importance to have multi-layered stands, both horizontally and vertically.

There are some differences concerning the forest cover density. Some managers recommend to have a quite dense cover, like in Munich or Vienna, some other prefer a clearer density, like in Vittel. But this is linked to the main species requirements. In Munich and Vienna, shadow tolerant species like beech or fir trees are favoured due to climatic restrictments and site conditions. In Vittel, it is mainly oak, which is a light demanding species.

To regenerate light demanding species, like larch, this plenter management is not possible. In Vienna, larch is therefore regenerated in strips in the « edges » of suitable parcels.Yet small gaps, which provide enough light and still are suitable for continuous cover forest management techniques (KOECK et al., 2007).

Light management remains one of the main challenges to find the right balance to regenerate all species adapted to forest site conditions.

- **Presence of deciduous trees**

When forest site conditions are suitable, managers favour deciduous trees or introduce them to have a mix with conifers.

Usually, managers try to have the most diverse species stands as possible.

This choice is related to scientific considerations: deciduous trees catch less pollutants and structure better the soil with their roots.

- **Dynamic and healthy vegetation**

The main goal of forest managers is to have stable, resilient, vigorous and site conditions adapted forest stands.

Stability in the time is the only way to guarantee continuous forest cover. And continuous forest cover is the key for good water quality. When a forest area is suddenly cleared, from natural or man activity origin, water quality is often affected. There are more suspended matter and bacteria.

This is why managers have chosen uneven-aged forest. They also try to have « natural » and adapted stands, with diverse species in order to resist better to wind throws and pests (LINDER, 2008).

Vienna and Munich apply a kind of precaution principle when they replace their spruce stands by more naturals species stands. These sites have no problem of water quality with spruce stands, but they fear that *Ips typographus* attack more and more forests and that the number of wind throws increases, particularly because of climate change. They do not want to take the risk to have suddenly huge forest area devastated. They want to minimize this risk to keep good water quality.

- **Careful forest harvesting**

Harvesting techniques have to be the most soft and soil-respectful possible: winter harvesting, cable yarding…

The level of precaution depends on soil vulnerability. If soils are not particularly sensitive, a traditional harvest is alright, with machines concentrated on skid roads, and by protecting the soil with cullwood.

It is important to underline that wood production is always possible. A forest with water protection objective is less profitable than a « normal » forest, but it is still productive. Production and protection are not contradictory, that is forest multi-functionality.

- **Pollution sources limitation**

In many sites, biologic oils are recommended or compulsory. Pesticides and chemicals treatments are forbidden.

These measures prevent from accidental pollution

- **Particular attention around sensitive points**

Around sensitive points (water catchment points, dolines or riparian forest), foresters adopt a very soft management.

The first step is to identify these areas and create vulnerability/sensitivity maps. Managers define then an adapted management in function of the degree of sensitivity. Usually, in very sensitive zones, machines are not allowed; forest work is realised manually and very softly.

5.2.3.2 And some disagreements

Some management aspects differ from one site to another.

- **Case of « Best Management Practises » in the USA**

The « best management practises » are a set of measures recommended by public forest services. They focus mainly on forest roads creation and maintenance and on river crossings (see appendix 4: Description of « Best Management Practises »).

These measures do not directly concern forest management.

New York forest administration recommends to forest owners to apply these measures and to have management plans, but there is no particular recommendation concerning the type of sivicultural management. Forest authorities consider that the essential is to a keep a certain forest cover, whatever management concepts and measures are applied there.

Erosion control and river protection are the key points to have a good water quality.

- **Case of Tokyo**

In Tokyo, the majority of forests is not managed. Managers think that the best management is to do nothing.

But this site is the only one.

- **Dead wood and cullwood: good or bad?**

In France, dead wood is seen as a problem, in particular in immediate protection zones. Managers fear that it brings too much organic matter and it is eliminated. In Masevaux (France), cullwood is even burnt in glens. On the opposite side, in Switzerland, it is forbidden to burn cullwood in water protection zones.

Other countries do not have this practise. In many place, dead wood is not a problem, even near catchment points. Dead wood means biologic activity and biodiversity, which is a guarantee of forest stability.

For example, in Vienna, a windthhrow recently devastated 20 ha of spruce plantation in a very sensitive zone for water protection. It was not possible to build a road to extract wood. The army helped foresters to debark 6, 000 m^3 of spruce to prevent from bark beetles attack. Logs have been let on the ground, to be naturally decomposed. No water quality problem has been detected by this excessive amount of dead wood.

- **Management near catchment points**

In France, immediate protection zones are usually cleared cut and fenced. Grass is cut regularly.

Again, France is rather isolated.

In Munich, a part of the forest stand just above water pipes is cleared, but not fenced. Superficial water pipes must not be blocked by a root. As soon as water pipes are deep enough, forest is not cleared anymore.

In Vienna, dolines are in some cases fenced, if cattle grazing poses a threat to water resources because of potential fecal contamination. In general they cannot be forested because of their specific site conditions (long lasting snowpack).

In America, the majority of drinking water comes from open air rivers. Therefore, riparian forest buffers are carefully conserved or restored.

Many managers believe that forest is the best protection around sensitive points, as long as roots do not degrade infrastructures.

All these considerations could lead French managers to change their practices in immediate protection zones.

- **Remark : case of private forest management**

When both public and private forests are present in a watershed, public forest management is usually more restrictive than in private forest. One can then wonder if these restrictive measures are really necessary. Forest managers think that they are, because the most sensitive areas are situated in public forest and they require a softer management and higher precautions.

5.2.4 Management recommendations

One of the objectives of my thesis is to give recommendations that should be applied to protect drinking water.

At the beginning of my thesis, I thought that it would be possible to build a typology of forest measures, in function of important site factors. But it has not been possible, because all the sites apply more or less the same forest management to protect their drinking water resources.

Therefore, I will recommend applying the same measures.

- Have a dynamic forest management to get stable, healthy and site suited species.
- Favour silvicultural treatments that guarantee a continuous forest cover: uneven-aged forest or even-aged forest with a long regeneration period.
- Favour species adapted to the site conditions and keep the widest tree species diversity possible (usually deciduous species), to mix with main tree species.
- Adapt harvesting methods in function of the site sensitivity (geology, soil type, topography…). The more sensitive the site, the more careful the harvest. Respect soils in any ways.
- Limit pollution sources: biologic oils, no chemicals, double tank wall machines.
- Do not build roads in sensitive zones, check that runoff water on roads is deviated from water catchment zones.
- Do not install game feeding places near sensitive points and prevent from game concentration there. Keep low enough populations to have sufficient regeneration.
- Do not develop touristic activities that can threat water protection, keep « soft » recreation levels.

The more sensitive the site, the more strict the application of these recommendations have to be.

These recommendations deal more with the qualitative aspect of water, than with the quantitative aspect. Water quantity is no problem for the studied sites, even if managers are conscious about the risk of seeing water quantity decreasing because of climate change.

It is very difficult to estimate if a particular silvicultural treatment applied to a particular species leads to more or less water consumption than another one, and therefore, has an impact on underground water quantity.

5.2.5 Conclusion about the types of action

All the sites have to face two necessities to protect drinking water resources: first the conservation of forest and then the application of adapted forest management.

In Europe, land acquisition has been the answer to these two challenges.

But if land acquisition has not been realised in the past, cities cannot buy today anymore huge forest areas (excepted sometimes immediate protection zones).

The new solution has been regulation. In many countries, regulations fix restriction to land uses situated in protection zones.

These restrictions do not lead to any compensation in forest, in spite of the over costs they imply.

In France, a recent decree allows farmers to receive compensation for the restrictions they have. But nothing is done for forests and regulation has reached its own limit.

Indeed, regulation guarantees forest occupation of soil, but it did not really manage to impose management restrictions, which led to today's problems.

In the USA, these two challenges have been solved in a different way. Authorities have developed contracts to conserve forest and, when it is necessary, to make land owners apply a different management.

This method is very different from the European one: gather owners and ask them which measures would work instead of imposing them tools that are not always efficient.

In Europe, authorities consider that forest multifunctionnality works « on its own ». But wood production does not always compensate for over costs linked to the others forest functions. In a sustainable development logic, these other functions should be remunerated to ensure that they will always be filled by the forest.

Land acquisition and regulation are not enough. Therefore news tools have to be developed. Contracts seem to be a satisfying alternative.

The contract diversity in the USA offers us huge perspectives. The application of the development rights principle, the remuneration as tax credits and the sale of tax credits between owners is not possible without an adaptation of our laws. Therefore, we could think of a possible adaptation.

But legislation is not the only obstacle for establishing contracts. Land owners, used to regulation, are not familiar with contracts.

Awareness raising, information and negotiation are preliminary steps to any contract process.

Propositions of such contract processes adapted to Alpeau sites are made in the next part of this report.

5.3 Application to Alpeau sites

5.3.1 Site analysis and diagnostic

The following table (table 8) presents the difficulties encountered at each site and the expectations of the managers. These sites, even if they are all different, have to face common challenges.

From the answers to the questionnaires I collected, I figured out these key points.

- In public forest, the silvicultural treatment is compatible with water protection. Forest stands are mixed, adapted to the site and managed so that they cover continuously the soil. The constraints are linked to harvesting methods that are very restrictive in protection zones.
- In France, in private forest, forest management can sometimes be a threat for water protection (clear cuts, barren soil as a resulet).
- In Switzerland, the problems are linked to the prohibition of chemical treatment of wood and of refuelling and parking of machines in S1 zones.

Sites	Problems cited by Alpeau partners	Expectations of Alpeau partners	Remarks
Areuse (Switzerland)	–	Lead scientific studies on the interactions between forest management and water quality	–
Arve (France)	Many water catchments, very divided ownership Some « dangerous » recreation activities Possible pollution from pastures	Know more about scientific studies on this topic Economic study to compare water production costs Think about changing prescriptions in PPI and PPR	The Alpeau partner is preparing a global water plan management
Broye (Switzerland)	Over costs linked to harvesting in protection zones Compensation not planned by law	Know more about scientific studies on this topic Create contracts to remunerate forest owners	Long thinking about creating contracts Precise Alpeau site not yet defined
Chambéry (France)	Sometimes difficult to apply law relative to water catchment protection	Know more about scientific studies on this topic Think about changing prescriptions in PPI and PPR Monitor water quality before, during and after a forest cut Create contracts to remunerate private or public forest owners	7 sites defined for Alpeau
Côte (Switzerland)	Over costs linked to harvesting in protection zones	Creation of a global project based on sustainable development, reorganize wood industry chain in the region	Long thinking about creating contracts
Lausanne (Switzerland)	Chemical wood treatment forbidden But small over costs	Promote water from forest Extend if possible the water catchment network in forest Monitor water quality of some sources	Precise Alpeau site not yet defined Tax on water → sustainable development fund
Moises (France)	Sometimes difficult to apply law relative to water catchment protection Some « dangerous » recreation activities Problems of bacteriologic pollution in water	Know more about scientific studies on this topic and on hydro geologic processes in this site Create contracts to remunerate private or public forest owners Think about changing prescriptions in PPI and PPR Manage forest belonging to the SIEM Secure and extend if possible the water catchment network in forest Economic study to compare water production costs	The Alpeau partner has the project to create a hydro geologic park

Table 8: Main problems and expectations of Alpeau sites managers

5.3.2 Suggestions

5.3.2.1 General suggestions

Some common suggestions can be made for several sites.

- **Know more about scientific research on the interactions between water and forest management**

Managers wish to know more about the interactions between forest management and water: which type of forest management can improve water quality and which forest practices can deteriorate this quality.

The aim is to define which rules are really important in respect to efficient drinking water protection.

The scientific review presented at the beginning of this report can be a starting point to answer this demand.

Experiments are planned on two sites, Chambéry and Neuchâtel (Areuse gorges). Forest cut are programmed near water catchment points and managers will monitor water quality during time. It will be interesting to see if forest cuts have or have not an impact on water quality, knowing that these two sites are in Karstic area, so rather sensitive (see 4.3.2, propositions for each site).

- **Develop exchanges between forest and water managers**

One of the main expectations of Alpeau partners is to multiply exchanges between forest and water managers. On many sites, foresters do not know anything about the water infrastructures and they are not told if water quality is suddenly degraded, so they cannot link it to an eventual forest operation. Water managers, on their side, complain about not knowing anything about what is done in forest near catchment points.

The Alpeau project has to give the opportunity to establish a partnership between these two « worlds ». Each partner has a lot to learn from each other and the results on water quality will only be better.

- **Think about changing prescriptions in PPI (or S1 zones)**

The majority of French managers wonder about the relevance of regulations in immediate protection zones (PPI). They are sometimes incoherent from one catchment to another and some practices are in opposition with scientific results.

With the study made in other countries, where prescriptions are different and where it does not lead to any problem, I would give the following suggestions.

- Forest is the best protection possible, much more than a meadow. If water pipes are situated in more than 2 meters depth in the soil, deforestation is useless (roots cannot go further). A deciduous or mixed uneven-aged forest is optimal.
- Soil should not be totally covered by cullwood, but foresters should not eliminate cullwood systematically.
- The obligation to fence PPI seems to be excessive. France is the only country to do that. Some cities, like Saint Etienne have managed to be dispensed of this obligation, and no problem ever happened there. The materialization of PPI with milestones, like it was done in Switzerland, seems to be very relevant, because foresters locate the protection zones very easily.
- In France, machines circulation is normally forbidden in PPI, which can be excessive for some cases. In Switzerland, circulation is tolerated in S1 zones.
- Drinking water protection is not incompatible with "adequate and adapted" forest activities (see 3.2.2.3, Management recommendations). However wood harvesting has to be more respectful,

which means cutting trees when the soil is the less sensitive, concentrating machines on skid roads situated far from water pipes, using biologic oils, not refueling in PPI, not parking machines in PPI, not using any chemical treatment. Clearcuts of course should be forbidden within drinking water protection areas.

- Prescriptions have to be adapted to each situation, in function of the catchment vulnerability.
- In France, in public forests, an agreement could be passed between water managers and the ONF, so that ONF foresters, when they make their regular surveillance round in forest, check also water catchment surroundings.

The major constraints in Switzerland come from the prohibition of treating wood and parking machines in protected zones. The treatment problem will be discussed later.

Concerning machines parking, the thing is that, in Karstic areas, S1 and S2 zones can be really huge and it is difficult to ask to a forest worker to make several kilometers at the end of day to park his machine outside of the protection zone.

However, managers do not all agree on law interpretation. For some of them, the prohibition of parking machines does not concern forest activities. A precision of this regulation is therefore necessary and in some cases, a compromise with authorities could be accepted if machines have a double fuel wall.

This recommendation could also be applied in France.

Lausanne city has adopted the following prescriptions in the protection zones. They are cautious but they remain realistic and allow forest management (table 9).

Activities or infrastructures	Zone S3 ~ PPE	Zone S2 ~ PPR	Zone S1 ~ PPI
Deposition of non-treated wood	o	o	x
Deposition of treated wood	x	x	x
Use of chemical sanitary products, herbicides, products for wood conservation, fertilisers	x	x	x
Burning of branches	x	x	x
Use of mineral oil and fuel (chainsaw…)	x	x	x
Use of mineral lubricants (machines…)	o	o	x
Refuelling of machines	o	o	x
Parking of machines	o	o	x
Clear cutting	x	x	x
Not intensive forest harvesting	o	o	o

Legend: o = allowed, x = forbidden

Table 9: Recommendations of Lausanne forest service in protection zones

Source: FODOVI (Service des forêts, domaines et vignobles de Lausanne). - *Zones de protection des eaux, restrictions et contraintes*

Two pictures (picture 2 and picture 3)taken in Switzerland illustrate the previous recommendations in S1 zones (~PPI).

Picture 2: S1 zone in Lausanne (June 2008)

Picture 3: S1 zone in Mont-Gibloux (June 2008)

Tha application of forest management concept or measure in a PPI can, in some cases, induce an ownership problem. Indeed PPI are usually bought by water managers. If this water manager owns also the forest around the PPI, like in public forest, having forest management measures within PPI does not provoke problems. The cases of Masevaux or Saint Etienne, where city services and ONF collaborate, are examples to follow.

But if the PPR belongs to a private owner and the PPI is too small or does not have any access road to be separately harvested, a contract should be established with the forest owner of the PPR. It could be possible to remunerate a passing right on the PPR so that managers can make harvest operations on the PPI.

But usually, water managers already dispose access to do the maintenance of the water catchment infrastructures in the PPI.

- **Inform forest owners**

Accidents happened in protection zones (in PPR mainly), and forest owners should be better informed. They have to know where these zones are and which prescriptions or restrictions have to be respected.

For that, meetings with forest owners should be organised by water managers. They should be explained, very simply, how infrastructures are, how water catchments work, how forest management influences water quality and what are the prescriptions to respect. It is really very important to explain them why they are asked to do so. Local forest owners will be all the more receptive as they themselves drink water from these catchments.

The example of Areuse gorges (Switzerland) is very interesting. Water quality was more and more degraded because of agricultural pollution. Farmers were not paying any attention to recommendation letters they were receiving from water managers. Therefore, water managers organised a meeting with farmers to make them visit the infrastructures, and explain where the water they were drinking was coming from. They then debated all together on farming practices that can affect water quality. Since then, farmers respect these small but necessary restrictions, without asking any compensation. And never any pollution accident happened again.

Meet, explain, discuss, motivate and give sense of responsibility can be the key for the solution of the problem.

- **Indemnify private owners**

Legislation in France allows the establishment of amicable contracts between forest and water managers. The objective of Alpeau is to create such contracts and not to create a legal framework where forest owners could be systematically indemnified, like it is done with farmers. The advantage of an amicable contract is that it does not only compensate for restrictions but it gives value to a real ecological service.

In Switzerland, the context is more difficult because the law says that forest owners have to apply a management that guarantees water protection. This is the problem pointed out by the research office in Soleure: few local authorities are ready to pay for something that is due to them.

An adaptation of law in Switzerland is therefore necessary and Alpeau could act as a lobby to raise awareness about the importance of this topic and to propose contract frames.

Concerning the method to evaluate and define indemnification rates, the principle suggested by the research office Kaufmann in Soleure could be adapted and applied (see 3.2.3.3.2). Economic studies could also help.

The process implemented in Florida, to gather owners and ask them to imagine which measures will make them change practices, gives a sense of responsibility and is motivating.

The creation of a fund to give indirectly money to owners that apply a protective forest management is also possible (see next paragraph).

In France, cities could, like in Saint Etienne, pass contracts with ONF to remunerate harvesting over costs and surveillance.

In both countries, over costs, when they take place in a public forest owned by a city, could be attributed to the water budget, and not to the forest budget.

- **Create a sustainable development fund**

The city of Lausanne has been very innovative with the creation of a fund for sustainable development.

A tax of 2 cents CHF is taken on each consumed m³ of water, as well as a tax on gas and electricity and also on industrial city services benefits. For information, this fund receives each year around 3 million CHF (~1, 800, 000 €). With this money, Lausanne develops several actions:

- Use and promotion of wood (« un arbre-un enfant », sawmill, bus shelter, pedagogic hut, parking, promotion of deciduous trees …),
- Research and studies,
- Public relations, communication, information,
- Support to associations,
- Education (sport, obesity prevention, waste recycling…)
- Other isolated realisations (children council, subsidy for gas vehicles, bio ethanol for public services, batrachians « roads »…).

For information, this fund finances a part of Alpeau project.

This example could be adopted in the case of other sites.

A part of the money collected could be used to remunerate foresters for their protective management.

- **Inform public**

Local population and tourists should be informed about the protective function of forests: explain to give a sense of responsibility and respect.

Two French sites underlined the risk of « dangerous » recreation activities, like motor circulation in forests, to become more frequent.

Some information is already available, but not enough. Other actions could be implemented to educate the public about the protection role of forests and the rules to respect:

- Diffuse in local media: newspaper, radio, tourism office, city hall…
- Create pedagogic trails in forest.
- Install informative notice boards in forest.
- Organise school field trips in forest.
- Organise field trips in forest for tourists and make them discover the functions of forests and how water catchments work. « Green tourism » develops more and more, people are more and more preoccupied by ecological problems. Therefore, this type of field visits would certainly be a success. Tourist offices could promote them and forest or water managers could organise, during school holidays, some visits in forest. The majority of French people do not know where the water they drink comes from. They would be very interested and happy to know that a part of the water is protected « naturally » by forests. These visits could be financed by public participation and by water services.
- Increase awareness of local inhabitants by annual celebrations. The city of Lausanne has created, for example, a celebration called « un arbre-un enfant », which means « a tree-a child ». Once a year, all the parents that have got a baby during the previous year are invited to plant a tree in forest.

If all these measures are not enough to control recreation activities, water managers could pass a contract with public services responsible for forest surveillance, like it is done in Saint Etienne where the city has passed a 2, 000 €/year contract with the ONF to increase surveillance against motorized circulation in forest.

- **Give up treating woods in Switzerland: reorganize wood industry chain?**

One of the major constraints for water protection in Switzerland is linked to the forbidding of log treatment to prevent bark beetles spreading. Sawmills do not have log storing places and therefore foresters took the habit to let logs in forest and be progressively absorbed by sawmills. Now foresters treat systematically conifers.

These practices are very difficult to change today. Even if the number of logs treated has decreased, a percentage of wood remains treated.

In Vaud canton, during the two last years, foresters have worked in constant flow with sawmills and no log has been treated. But this was possible only because the market was favourable during this period.

The idea of managers is to re-organise the entire wood industry chain. Local sawmills should be helped to create log landing places.

The Alpeau project can be the opportunity to give a frame and legitimacy to this discussion.

- **Promote a local use of wood and communicate intensively**

Shorten wood supply circuits is also a challenge.

Cities could use directly the wood from their forests and promote it. Build benches or bus stop shelters made of wood from « forests which protect water » would certainly have a very positive feedback from local inhabitants. Lausanne city has already implemented such actions and this is an example to follow. In Vienna, Christmas market huts are made of wood from Viennese forests and inhabitants are aware of the protective management applied there.

Alpeau has to intensify communication about wood produced in these forests. The public has become very sensitive to « forest stores Carbon »; it would also adhere to « forest protects water ». Cities would by the same way acquire an innovative « green » image, based on environmental services remuneration.

The creation of a common certification for Alpeau sites could also be a possibility. A certification could promote locally « the forest which protects water » and help to remunerate partly forest owners for their protective management. The certification would be innovative because it recognises a function, and not a provenance, like the example of « Salmon safe » in the USA (see 2.2.4.2). But creating a label is very long and difficult to implement, it is beyond Alpeau missions.

5.3.2.2 Specific propositions for each site

- **Site of Areuse gorges (Switzerland)**

This site situated within a karstic area does not have the objective to establish any contract. The aim of Neuchâtel University is to conduct scientific experiments to learn more and evaluate the impact of forest management on underground water quality.

The studies planned by François Zwahlen, the director of the hydrology centre of Neuchâtel University, are:

- Study data collected since more than 40 years on water quality to try to link it with past forest operations, in function of soil vulnerability ;
- Study thoroughly some experimental sites to measure physic-chemical water quality in function of forest type and management.

- **Site of Arve (France)**

No precise water catchment area has been chosen for the moment. It is planned to realise an inventory and a typology of all the water catchments of the Arve watershed during the Alpeau project. Particular actions could then be implemented in 2-3 of the most interesting/representative ones.

Potentially, 250 to 300 water catchment points are concerned, of which more than half are in forest. Forest ownership is mostly private and much divided.

If Alpeau partners want to establish minimal rules of forest management to implement on every water catchment areas, some suggestions can be given.

Firstly, managers should be sure that all private owners know that their forest is situated within a protection zone and that they are aware of what it implies.

Regulation constraints could be adapted to each water catchment in function of forest activities and protection stake. A GIS program could help to determine the most vulnerable catchments. Constraints would then be higher (restrictions on harvesting methods). For low vulnerability catchments, tolerance towards forest activities could be larger.

If the SM3A (Alpeau partner) or local authorities directly concerned wishes to go further, it would be possible to establish contracts with owners if they accept to adopt another forest management, like the one applied by the ONF (see paragraph on the Moises site).

In any case, information of owners and public should be abundant. Water managers should tell forest managers which type of water catchment is in their forest and where water pipes are to prevent from accidents.

Lastly, forest surveillance should be strengthened.

For information, the sites of Arve and Moises plan to conduct economic studies to compare the cost of the different water supply types.

A first study has to compare the production costs of drinking water between pumping in water table (electricity, treatment…) and collecting water from forest (treatment, cost of forest management…). The ultimate goal is to evaluate the financial saving provided by forest water supply.

The second study, which concerns forest water catchments, has to estimate the production costs of water in function of forest management:

- Cost associated to a « preventive » forest management (technical cost of a different siliviculture, information/education cost, control cost),

- Cost associated to a « curative » management (no measure to manage watershed forest, but measures to purify water and to face probable accidents).

- **Site of Broye (Switzerland)**

If the Mont-Gibloux forest is chosen to be the precise Alpeau site of the Broye region, some improvements can be proposed there. This forest is public but owned by 5 different cities.

If the same city owns the catchment point and the forest around, over cost linked to the protective forest management could be attributed to the water budget of the city.

If the water catchment belongs to another city, the city that benefits from water could indemnify the city that owns the forest for the restrictions in forest management.

The main constraints are the prohibition of wood treatment and accessibility in S1 zones.

Concerning the chemical treatment, the cities could agree to extract from forest in priority logs situated in protected zones. A log landing place could be created in a not sensitive zone. And in case that wood treatment could not be avoided, special equipments could receive polluted water runoff from the treatment place.

Concerning the accessibility of S1 zone, a hydro geological study could confirm or infirm the forbidding to build a road to access in S1 zone. Winter harvest, when soil is frozen, could be allowed. Cable yarding could also be an alternative. Machines with double fuel wall could be allowed.

- **Site of Chambéry (France)**

Seven water catchments are planned to be studied, four of them are already fixed.

- The PPR of the catchment called « Dhuy » is situated in a zone recently devastated by bark beetles. Forest stands are in regeneration. The constraints are therefore almost inexistent for foresters. Concerning the PPI, managers could try to modify the regulation adopted there, not to deforest it.
- The PPR of « Pierre Rouge » catchment is situated in public forest, treated in coppice and standards. This silvicultural treatment has not been very detailed in scientific research and therefore it would be very interesting to plan a coppice cut and to monitor its influence on water quality.

- The PPR of « Fontaine Froide » catchment is also located in public forest. A selection cut is planned during the coming years in one of the parcel of the PPR. Here again, water quality could be monitored before, during and after the cut.

  Another water catchment is situated very near from « Fontaine Froide », site conditions are the same for these two catchments. A selection cut has also to be done in the PPR. A cut could be made in the PPR of each catchment, but the intensity could be different, to see if this has a different impact on the water quality from each catchment.
- The determination of protection zones of the « Fontaine Noire » catchment has not been done yet. Managers wish not to deforest on the future PPI, which is for the moment covered by a mature spruce plantation. The solution could be to regenerate this spruce stand, by little openings, and to favour beech trees and firs (corresponding to the « natural » forest site).

  The water from this catchment has a low quality (lot of suspended matter and bacteria, linked to pasture land above, and too much Iron in water). Therefore, water is ultra-filtered. All these problems could hide a possible positive effect from forest and as a consequence, monitoring efforts should not be concentrated there.

  However, several private forests are present on the PPR and an owner association could be created there (see paragraph of the Moises site).

- **Site of Côte (Switzerland)**

The cities of Gland and Aubonne that are chosen to be the precise working sites of Alpeau, do not own forests that protect their water resources but they feel very concerned by sustainable development.

Gland is very motivated to give value to water coming from forest streams. These streams come, for the majority, from forest in Karstic area, which belong to other cities. Gland could sign a contract with these cities that have management restrictions to compensate for the over costs they undergo.

Aubonne owns 450 ha of forest down in the plain, but they do not directly protect the water resources. Aubonne water comes from an artesian resurgence and it is therefore impossible to define any protection zone around

These two cities could join to form a global project based on sustainable development and valuate a regional use of wood, by re-organising the wood industry chain, shortening wood use distances and informing public.

To finance this program, a sustainable development fund, like in Lausanne, could be created.

This project could also allocate land for soil transformation firms. Indeed, land is very expensive in this region and an owner/manager cannot buy land to build a sawmill for example. So if the city sells him a piece of land cheaper, he will be able to create a sawmill, logs will be extracted more easily and quickly from forests and they will not be treated.

The Alpeau project could give an impulse to this program.

- **Site of Lausanne (Switzerland)**

No precise water catchment has been designated yet.

Constraint compensation is not really a problem for the managers of Lausanne forest. They wish, with Alpeau, to promote water yielded from forested watersheds.

Managers consider also the possibility to extend the water catchment network in forest.

The Alpeau project could give the opportunity to monitor more precisely the water quality from some catchments. Forest cuts could be realised near them, like in Chambéry.

- **Site of Moises (France)**

The department of Haute Savoie is characterised by a very strong forest ownership division and the parcels are very small (3, 000 m² in average). When owners manage their forest, which are mainly spruce plantations, they clear cut them. Normally, in protection zone PPR, clear cut superior to

5, 000 m² are not allowed. But forest cooperatives manage to group owners that have contiguous parcels, each one smaller than 5, 000 m², but realise on each one clear cut. Therefore, the cumulated area clear cutted can reach several hectares, which represents a real danger for water protection. In addition, they usually, in order to clear the soil after, gather cullwood on strips, and plant spruce between, although natural vegetation works perfectly (natural seedlings come into artificial plantation).

These practices should change.

After a meeting with the president of the Haute Savoie forest owner association, it was concluded that it would be possible to create an owner grouping around the Moises catchment points.

The Alpeau partner on this site, the SIEM (Alpeau partner), which is the joint association that supplies water, could sign contracts with forest owners of this grouping. Forest owners will receive money from the SIEM to be compensated of changing forest practices and remunerated for the protective management they have.

The ideal forest stands would be mix species stands, with an adequate proportion of broadleaved tree species, treated in the selection system; but this ideal will be difficult to apply.

The SIEM could then propose to owners to harvest their spruce stands by small openings (tree group or strip) and extend the regeneration period to 10-20 years (instead of clear cutting all the trees at once). Spruce trees would be cut around gaps where natural regeneration is already present, and deciduous tree seedlings could be kept also. The ONF already adopted this management since more than 10 years to progressively replace spruce plantations. Forest owners could « copy » this management (picture 4).

The grouping of several contiguous parcels would make the harvest operations profitable, even if only a small percentage of volume is harvested in each parcel.

This new type of sivicultural management requires less forest work but more knowledge and control. It requires also more surveillance during harvest operations to make sure that the remaining trees are not injured and that soil is respected.

Picture 4: forest management applied by ONF in Arraches public forest (Haute Savoie), a selection cut of large diameter trees has just been done in the spruce stand (July 2008).

Information and education of forest owners will be very important. Information meetings on the impact of forest management on water quality will have to be organised.

The SIEM should also apply this management on the forest lands it recently acquired. Demonstration forests, to teach owners which trees to mark to be harvested, could be created in these parcels.

This forest management could be controlled by the SIEM, the forest owner association or the ONF within a convention frame.

The remuneration given by the contract would constitute a strong incentive to join the forest grouping and adopt new silviculture. The SIEM would, on its side, secure water resources and acquire a « sustainable development » image to the eyes of the public and local authorities.

The SIEM would like to establish this frame of contracts with all the forest owners situated in the future hydro geological park they are planning to create, which means all the parcels situated around the catchment points, in or out protection zones. The level of management restrictions (and therefore the level of remuneration) asked in the contract could be adapted to the sensitivity of each parcel towards water protection.

6. Critical analysis of the study

6.1 Discussion of the method

- **Limits of the study**

The research of information about sites, throughout the whole world, that have implemented a particular forest management to protect drinking water resources could be improved and extended. A more exhaustive inventory has not been made because of lack of time. Sites known too late could not be studied. And information about sites studied here remains sometimes incomplete.

The sample constitutes only of sites from Western Europe, the United States and Japan. The study would have been richer with sites from South America, Asia, Africa or Oceania.

The study of Alpeau sites is also limited. It was not possible to collect information collected for all the sites. Some Alpeau sites have not chosen their precise research water catchment for the project. Therefore, a lot of information is lacking to be able to improve or give more appropriate recommendations.

However, all Alpeau sites have been visited and managers met, as well as in Saint-Etienne, Vittel, Masevaux, Vienna and Munich. These visits and the direct exchanges with managers have brought a lot to my study.

The lack of juridic knowledge about the legal possibilities to establish contracts in France and in Switzerland is regrettable. Once again, time was too short to acquire competence in this field.

- **Debatable points**

The grading method to compare sites lacks of scientific validity: too much subjectivity to choose criteria, to fix thresholds and to evaluate each site. But the goal of this classification was only to determine which sites were to be studied in priority to give them more time, but all the sites have been studied anyway.

The realisation of a multi-criteria analysis has been considered; but the too small sample would not have given interesting results.

The data collection has been made from Internet web pages, mail exchanges and field visits. But, for some sites, the contact person did not speak English well enough to go into details or could not answer all my questions.

- **Possible improvements**

The knowledge of juridic and legal contexts about the regulation in each country about the protection of water catchment is lacking, therefore I would include questions about this topic in the questionnaire.

- **Outcome of the work**

The objectives of this thesis have been reached:

- The international case studies have been realised; management recommendations have been formulated, according to the experience of the sites studied and to the scientific synthesis made about the interactions between drinking water and forest. Main types of forest management implementation have been identified (land acquisition and contracts).
- The Alpeau sites have all been studied. General and specific recommendations have been suggested to be implemented during the Alpeau project. This work has also created a contact with and between Alpeau partners.

6.2 Discussion of results

Many sites in the world have understood that forest plays a very important role to protect water and have implemented particular forest management concept. Forest alone is not enough; an adapted management has to be conducted.

- **Forest management and scientific research**

It has not been possible to determine keys factors leading to one type of forest management or to another one. Almost all sites apply the same forest management. This observation is explained by the fact that managers, in each site, referred to scientific literature to define their management rules. As a consequence, they all apply the same principles, all on their side.

Most of the managers recognized ignoring if any other site, where forest protects water, exists. They have been reassured to learn that in other sites, the same management rules were applied and they said they were interested in exchanging experience with forest managers from other countries on this topic.

Forest practices can be compared to the precaution principle. As managers do not know exactly which harvest operations or silvicultural treatment can have a negative influence on water quality, they prefer not to take risk and be careful.

Scientific studies always bring news answers, despite of the results that are sometimes contradictory.

It is interesting to develop studies where effects of forest cuts on water quality are monitored during time. Such experiments are planned on Chambéry and Areuse gorges.

Two aspects are lacking in scientific research:

- Define a scale of importance of forest management in function of site conditions (for example, it seems to be more important to have a soft forest management on a very sensitive soil, than on a less sensitive soil). The keys factors (soil, geology, topography…) could be determined and the importance of forest management quantified.
- Determine if a particular forest stand (species composition, silvicultural treatment…) allows higher or lower quantity of water infiltration into the soil.

Concerning management rules near water catchments, this study shows how France is isolated with the practise to deforest PPI. In other countries, forest is considered to be the best protection. The Alpeau project could lobby to change these prescriptions.

- **Land acquisition, regulation and contracts**

Regulation is the main tool used in France and Switzerland, and there are still problems of water catchments protection.

Europe begins to think of establishing contracts with foresters.

Signing contracts with foresters both indemnifies constraints they have and valuates ecological functions of forest.

The logic of contracts is not well introduced in our minds. It is not easy to establish a contract system with owners who have always been used to regulation without compensation.

Legislation in Switzerland is a major issue. It will be difficult to create new tools without changing it. Law recognises constraints for farmers and gives access to financial compensation. One of the challenges of Alpeau will be to promote forest functions and to propose contracts to make these functions sustainable.

Some initiatives can be adapted to create new contracts: sustainable development fund, system of indemnification with points (Swiss research office), contracts between water and forest services…

A working group could see how American contracts may be adapted in Europe: development rights principle, financial compensation by tax credits and sale of tax credits between owners…

Alpeau has really to make of water protection an ecological product that foresters can sell.

- **Other ambitions for Alpeau**

Develop contracts with forest owners to give an incentive to change forest management is necessary, but it is only one step. Some Swiss managers suggest that the whole wood industry chain should be re-organised : shorten wood supply circuits, create local use of wood, help firms to settle down, promote a regional use of wood, raise public awareness…

This ambitious idea is maybe feasible within the frame of Alpeau which could start the debate, communicate heavily of this issue and implement first actions.

Alpeau raises really huge perspectives and expectations.

7. Conclusion

Forest is certainly the best cover to protect drinking water resources. But is this protection independent from the forest management applied?

Several sites in the world have answered « no »: the only presence of forest is not enough; a particular management has to be implemented.

This protection, improved by an adapted management, is an answer to both economic and ecologic considerations: it is more profitable and wiser, in a logic of sustainable development, to protect watersheds than to build huge filtration plants.

The prospective study that has been realised shows that the majority of sites applies very similar forest management concepts.

The aim of this management is to obtain stable forest stands, adapted to forest site. They are, if possible, mixed species stands, with deciduous trees, diverse in age and structure, so that soil is continuously covered by forest (continuous or selection forest). Harvest operations are made carefully, to respect soil. It is about this last aspect that sites differ mostly. In function of site vulnerability, the precautions to take are not the same. Lastly, at all sites the potential pollution sources are eliminated (use of biologic oils, absence of pesticides or chemical treatment).

Today, managing a forest to protect water implies implementing these recommendations, and adapting the « harvesting precautions » to the level of sensitivity of the given site.

Europe has chosen since long time land acquisition to implement this management, which can be very effective. But when forest remained private, countries edited regulations to impose to owners to conserve forest occupation on their land and to forbid some activities. No compensation ever accompanied these constraints, which explains that today, regulation has reached its limits, without filling all its objectives.

The United States of America have chosen to establish contracts since the beginning. Owners voluntary accept a certain restriction in exchange of an incentive financial compensation.

In front of this situation, Europe begins to implement also contracts with owners.

The ultimate goal of Alpeau is to create European tools to establish contracts to secure in the long term water resources and remunerate fairly forest owners. Water yielded from forested watersheds is cheap and, generally, of good quality. In a logic of sustainable development, it becomes crucial to protect and develop forest water, all the more as other water supply sources begin to face micro-pollution problems.

An adapted management of these forests and a positive cooperation with owners is a necessity. Contracts work very well where they have been introduced and Alpeau partners are motivated to do so. Practical recommendations have been suggested to each Alpeau site. Some forest managers wish that Alpeau project will give the occasion to think globally and re-organise the whole wood industry chain.

To conclude, drinking water in forest is not a « non-problem », not even a problem, it is a formidable asset.

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