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THE EVAPORATION FROM PONDS IN THE FRENCH MIDWEST

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Abstract

This research shows the results of a study about evaporation in five ponds in the Midwest of France. To realize this study we used climate data from the meteorological station of the Limoges-Bellegarde airport and the data of a weather station installed by us near one of the ponds. We used eight different methods to calculate the evaporation rate and we modified the Penman-Monteith method by replacing the air temperature by water temperature. To understand the role of ponds in water loss through evaporation, we proposed a hypothesis that says : if the pond did not exist, what results would we get? Based on this hypothesis we calculated the potential evapotranspiration rate taking into account the percentage of interception by vegetation. In conclusion, this study indicates that the ponds in the French Midwest present a gain of water.

Keywords: Pond, Evaporation, Potential evapotranspiration, French Midwest, Limnogeography

INTRODUCTION

Studies about evaporation on lakes and reservoirs are not a very common part of the limnological researches, except in hot and arid zones (Bouchardeau & Lefèvre, 1957, Riou, 1975, on Lake Chad, Neumann, 1953, on Lake Houle and Lake Tiberiade), except for great lakes (Afanas'ev, 1976, on Lake Baikal, Nicod J. & Rossi G., 1979, on Lake Victoria) and except for emblematic reservoirs such as Mead in USA (Anderson & Pritchard, 1951).

But the studies about evaporation on very small artificial bodies of water situated in headwaters, i.e. ponds, are still more exceptional. The problem of loss of water in European headwaters represents a more and more important challenge for the authorities.

In the context of sustainable management of water resources many decrees have been published to achieve the goal set by the Framework Directive (WFD) of 23 October 2000, the Water and Aquatic Environments Law of 30 December 2006 and the Grenelle Environment Forum.

All the local authorities dealing with territorial development and the various water users will have to integrate all these regulations and adapt their doctrine and practice to these new realities.

One of the high stakes of these new regulations is the water balance of ponds. (Ponds are suspected of great losses by evaporation q.v. J. le Bihan and M. Font, 2008, p. 7). Very high values are sometimes cited. According to H. Carmie, director of the regional “Périgord – Limousin” natural park, the French ponds evaporate 0.5 liter per second per hectare, which is equivalent to more than 43 millimetres per day. It is probably significant that these figures are presented in the same institution (EPTB) that published a report entitled "erasing ponds, one option to consider" (Anonyme, 2010). In fact, some of these claims are based on the extrapolation of data derived from studies about the hot areas, others are drawn from a coincidence forced between the total of losses and evaporation alone , however most of them have no methodology. Direct measurements are systematically evacuated and formulas used neither cited nor criticized.

That is why this research is focused on the measurement and calculation of the evaporation of small water bodies submitted to a temperate oceanic climate, the ponds of French Midwest. This research investigates water losses by evaporation among the group of Water losses (outfall, infiltration) and studies the water balance of gains and losses (direct precipitation, runoff diffuse, tributaries, exfiltration) at different spatial and temporal scales.

1. Study site: the selection of five ponds in French regions Limousin and Berry

P. Bartout recorded 16 970 ponds in the geographic-administrative region Limousin (2006) and 35 873 in the administrative region Centre, among which 12 603 in the Berry region (comm. or, unpublished P. Bartout).

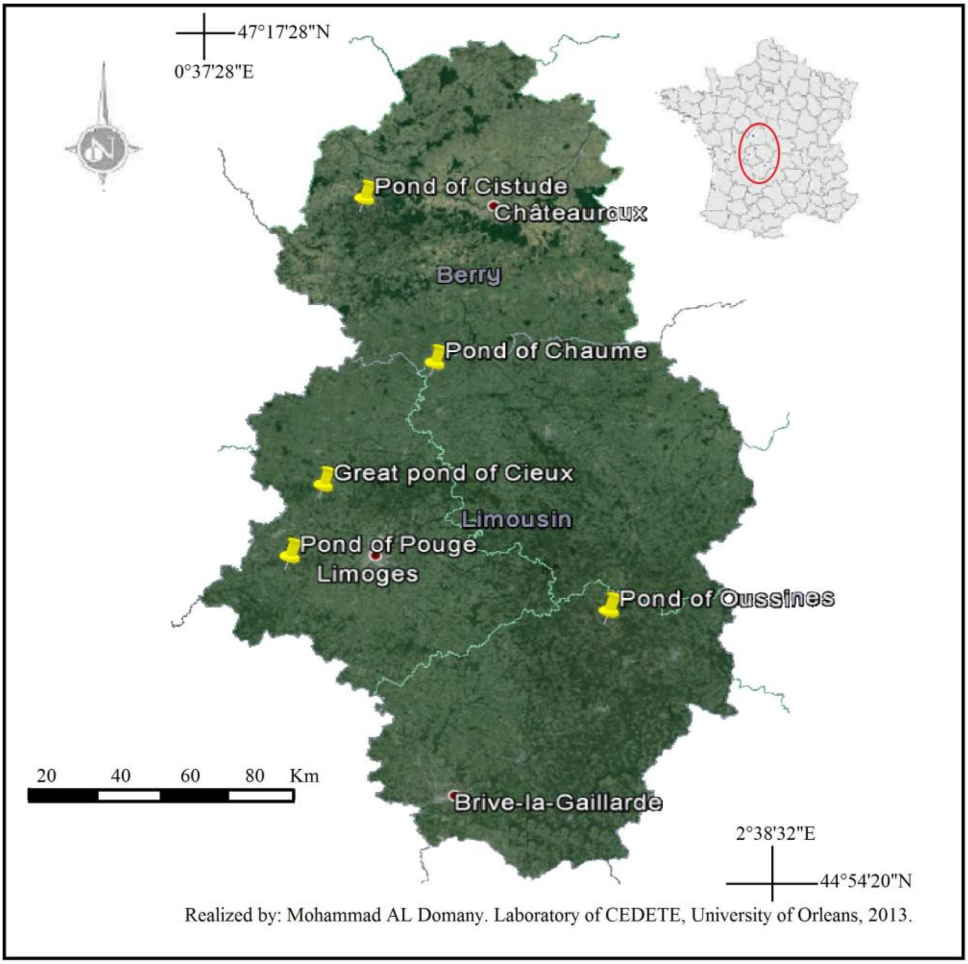

Fig. 1 The location of the five ponds studied in the French Midwest

This study selects five ponds by the criterion of continuous measurements of water temperature by L. Touchart in Region Limousin and M. Al Domany in Berry Region.

The morphometric characteristics of four ponds (Cieux, Pouge, Chaume, Oussines) in Region Limousin are well-known (Touchart & Graffouillère, 2004). The main features of one pond (Cistude) in Berry Region are done by (Al Domany, 2013).

The Great pond of Cieux is situated on the southern foothills of the Monts de Blond, at the confluence of latitude 45°59'22.47"N and longitude 1° 3'22.27"E. This pond covers 34.6 hectares and the overflow is located at an altitude of 290 meters. Its maximum depth is 3.69 meters. This pond is located in a representative area of low Limoges plates in a hyper oceanic climate: normal rainfall is 1000 mm and the average annual temperature is 10 degrees (Carlini, 2006). Like many ponds in this area, it is located on a granite substrate.

The Pouge pond is located on the plateaus of western low Limousin, at the confluence of latitude 45°47'22.27"N and the longitude 0°56'11.69"E is also located on a granite substrate, but with a lower total rainfall 900mm. It has an area of 32.2 hectares and the average water level stands 251.8 meters above the sea level. Its maximum depth is 5.98 meters.

The Chaume pond is located southwest of Commune of Azérables, at the confluence of latitude 46°19'50.95"N and longitude 1°27'7.84"E. It is 1.5 km long and 300 m wide, with a surface of 36.2 hectares. It is located on a substrate of Mica schist and gneiss, but with a total rainfall of about 900 mm. The pond never silts thanks to its continuous stream of water.

The Oussines pond is located on the Millevaches highlands, the heart of the mountain Limousine at the confluence of latitude 45°38'8.56"N and longitude 2° 3'57.59"E, it is set on a granite substrate. The Oussines pond pours its waters to 836 meters, and its catchment area (21.9 km2) has the second summit of Limousin culminating in the Puy Pendu which is 973 meters high. This pond is the highest in Limousin, it has an area of 14,7 hectares. It receives an average rainfall of 1400 mm. Its maximum depth is 2.4 meters.

The Cistude pond is located in the nature reserve of Cherine. It is 3 km east-southeast of Saint Michel en Brenne at the confluence of latitude 46°47'34.88"N and longitude 1°11'58.33"E. This pond covers 8.82 hectares and the overflow is located at an altitude of 280 meters. Its maximum depth is 2 meters. This pond is located in an area of hyper oceanic climate: normal rainfall is 789 mm. It is set on modal brown soils, mesotrophic.

2. Methodology: an addition of instrumental measurements and theoretical calculations about evaporation

To conduct this study, we started to show the different factors that influence evaporation. We classified these factors into two groups, the first group includes the meteorological factors such as air temperature, wind speed, barometric pressure, relative humidity and water temperature. In the second group we put the physical and geomorphological factors.

Then we talked about the different instruments used to measure weather parameters that influence on evaporation, and we also talked about the instrument used to measure the evaporation directly.

Then we showed the different methods used to calculate the evaporation rate which depends on one or more of the climatic parameters. We also showed the strengths and weaknesses for each of these methods in order to choose the best to use to calculate the evaporation of the ponds studied in this research.

Finally, we spent the last part of this research to study the evaporation of the ponds and the role played by these ponds on water loss by evaporation.

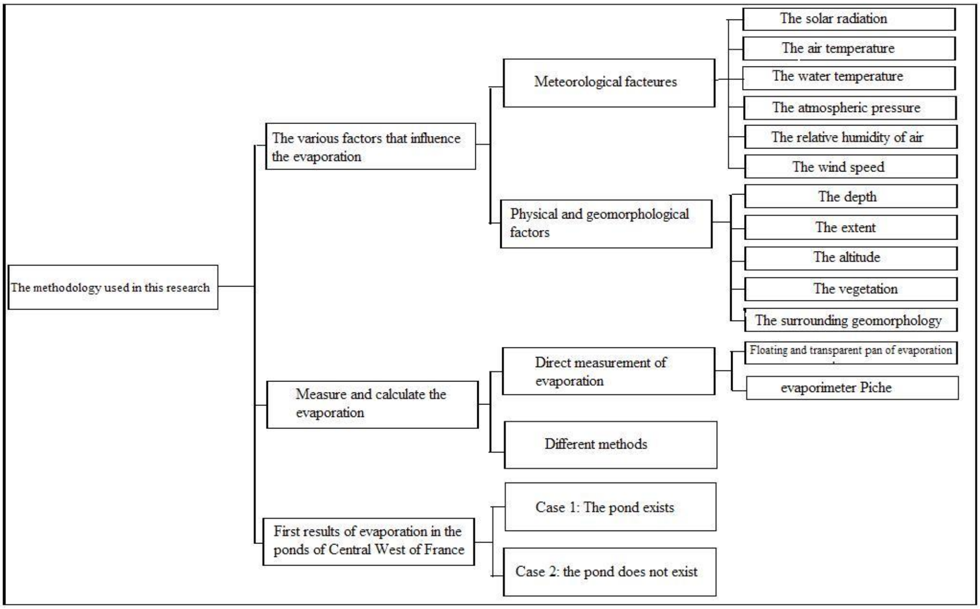

Fig. 2 The methodological arborescence

2.1. Instrumentation

To conduct this study, we used several instruments to measure the various climate parameters that have an influence on evaporation and the instruments that measure evaporation directly. These instruments are:

2.1.1. The meteorological station (Weather Monitor II)

The meteorological station Weather Monitor II consisted of miniaturized sensors and connected to a center console with an electronic system. Everything is managed by the WeatherLink software. The rain sensor, the external sensor of temperature and humidity, the anemometer and the barometer are used to obtain nine types of data, from direct observation or recalculated from these parameters.

All sensors are mounted on a tripod completed by two tubes extending up to about three meters. The tripod additionally supports the solar cell that allows the station to be fully autonomous.

The installation is completed by a junction: the entrance is reserved for data measured by the sensors, the output transmits the data to the interface of analysis and display that is the console.

The console allows instant display of outdoor and indoor temperatures, dew point temperature, the wind chill temperature, degree of indoor and outdoor humidity, daily and cumulative rainfall, speed and wind direction.

It is permanently connected to a recorder. Without computer, it allows you to view data in real time and configure some settings. However, using the supplied software, WeatherLink, greatly facilitates manipulations and allows partial use of data. It also includes useful functions calculated.

2.1.2. Water temperature recorder (Tinytag Data Loggers)

When we measure the evaporation, it is very important to know the surface temperature of the water. We used the water temperature recorder, it is Tinytag Data Loggers whose measuring range is -40 to 85 ° C.

The sensor is internal, and the response time for data acquisition is 8 seconds. The resolution is a tenth of a degree and accuracy announced by the manufacturer of two-tenths, which allows a suitable thermal approach. Their small box (a box whose base measures 78mm wide and 50mm long, its height is 38mm) is classified as "IP-68" and water resistant to 15m deep. Its weight is about 140 grams. The Tinytag Data Logger can store up to 7900 data and even 16,000 data for the most recent. Their energy independence is provided by lithium batteries.

2.1.3. Instrument used to measure evaporation

- The Piche evaporimeter

The Piche evaporimeter consists of a cylindrical glass tube 25 cm long and 1.5 cm in diameter. This graduated tube is closed at its upper part, while the bottom opening is closed by a circular filter paper sheet of standard 30mm diameter. The apparatus was filled with distilled water which gradually evaporated through the sheet of filter paper, a lower level of water in the tube is used to calculate the rate of evaporation (in mm per 24 hours per example), the evaporation process here is essentially related to the vapor pressure deficit of the air.

In this research, we have two Piche evaporimeters. We installed the first just below the meteorological station Weather Monitor II, and the other is located near the evaporation pan.

- The transparent floating evaporation pan

It is a transparent rectangular plastic pan measuring 52.5 cm x 36.5 cm from its upper side and 48.5 cm x 32.5 cm from its bottom side, its depth is 20 cm; its surface is about 0.2 m^2 . It is placed directly in the water.

The evaporation is measured using a gauge hook, graduated in millimeters on the central rod, the system allows an accuracy of 0.05 mm in our case. This gauge is placed in a stilling well of 10 cm in diameter, installed in the center of the pan to ensure balance when we put it in the water.

This well allows reliable measurement because it protects the water which is inside from the wind and keeps the surface of the water completely flat. The water level is maintained between 12.5 and 16 cm.

The main drawback of this instrument is that measurements may be biased on windy days by the water introduced into the pan by the waves, or discharged under the action of rolling movements. There is also a problem of docking and stability on the water level variable.

Nevertheless, this pan is most reliable, because it is in constant contact with pond water so the water temperature into the pan is consistent with that of the pond. In addition, because it is made of transparent plastic, so the solar radiation passes through without mounting the water temperature as in other types of evaporation pans.

2.2. The methods used to calculate the evaporation rate and ETP

Until now there is no instrument fully satisfactory for the direct measurement of evaporation. For that we used different methods to calculate the evaporation rate using one or several climatic parameters.

In the Table below, we see the methods and parameters that are required for each of them. We found a weak point in the Penman- Monteith method , that is the method only takes into account the temperature of the air. But as we all know , the water temperature is higher than the temperature of the air when we study evaporation. For this, we modified the Penman-Monteith method by using the water temperature instead of air temperature.

In this research, we have the weather data coming from the station Meteo-France of Limoges-Bellegarde for the ponds of Cieux, Pouge, Chaume and Oussines. Because this station is not located at the same altitude as these ponds, we made a correction of these data by using specific equations. In addition, we have data on water temperature for each of these ponds through aquatic thermometers installed by L. Touchart since 1997 (Touchart, 1999).

Table 1 The different parameters used in the formulas about evaporation

	Air temperature	Water temperature	Relative humidity	Wind speed	Global radiation	Atmospheric pressure	Calculate the rate per month	Calculate the rate per day
Kotoda	X	X		X				X
Penman-Monteith	X	(X)	X	X	X	X		X
Turc	X		X		X		X	X
Rohwer	X		X	X				X
Jensen-Hause	X				X			X
Stephens-Stwart	X				X			X
Paradahis	X		X					X
Papadakis	X		X					X
Holdridge	X						X	
Carnier	X		X				X	
Thorthwaite	X						X	

As for the Cistude pond, we have weather data coming from a meteorological station Weather Monitor II, installed 50 meters from the pond. We also have data on the temperature of water coming from an aquatic thermometers installed in the pond at 20 cm depth.

With these data we calculated the rate of evaporation for these ponds using eight methods that calculate the evaporation in mm per day.

3. Results: an evaporation rate of about 800 mm per year?

Calculated results are done only for periods when we have water temperatures (hourly water temperatures; data L. Touchart). According to the Penman-Monteith formula, modified by water temperature, the evaporation is 380 mm on the Cieux Great Pond from 22nd October 2000 to 27th July 2001, 275 mm on the Pouge Pond from 13th April 2000 to 4th

September 2000, 106 mm on the Oussines Pond from 22nd April 2002 to 19th June 2002, 28 mm on the Chaume Pond from 5th October 2007 to 13th November 2007 and 168 mm on the Cistude Pond from 13th August 2013 to 29th October 2013. Of course, it is almost impossible to extrapolate from different ponds and various periods, but the annual amount of evaporation on these ponds seems to be between 700 and 850 mm.

Measured results are done only for the Cistude Pond in a short time. The evaporation rate measured by the floating pan between the 9th August 2013 and the 29th October 2013 is 234 mm, the evaporation rate measured by the Piche evaporimeter which is installed below the weather station (Weather Monitor II) between 14th August 2013 and 29th October 2013 is 129 mm, and the evaporation rate measured by the Piche evaporimeter which is installed near the floating pan between 14th August 2013 and 29th October 2013 is 169 mm.

4. Discussion about the influence of the presence or absence of pond on water balance

To understand the role of ponds in the loss of water by evaporation, we launched a hypothesis that says: if the pond does not exist, what results we are?

According to this hypothesis, we proposed that the oak and the beech trees replace 60% of the pond surface, the plants of bulrush will occupy 35% and the rest replaced by the waterway.

According to this hypothesis the ETP rate is 231 mm on the Cieux Great Pond from 22nd October 2000 to 27th July 2001, 170 mm on the Pouge Pond from 13th April 2000 to 4th September 2000, 52 mm on the Oussine Pond s from 22nd April 2002 to 19th June 2002, 12 mm on the Chaume Pond from 5th October 2007 to 13th November 2007 and 178 mm on the Cistude Pond from 13th August 2013 to 29th October 2013.

By comparing the results we have obtained in the first case (the pond exist) with the results we obtained in the second case (the pond does not exist), we note that the rate of evaporation in most of the ponds is higher than the rate of ETP.

But, can we say that, according to these results, the ponds are a major resource of water loss by evaporation?

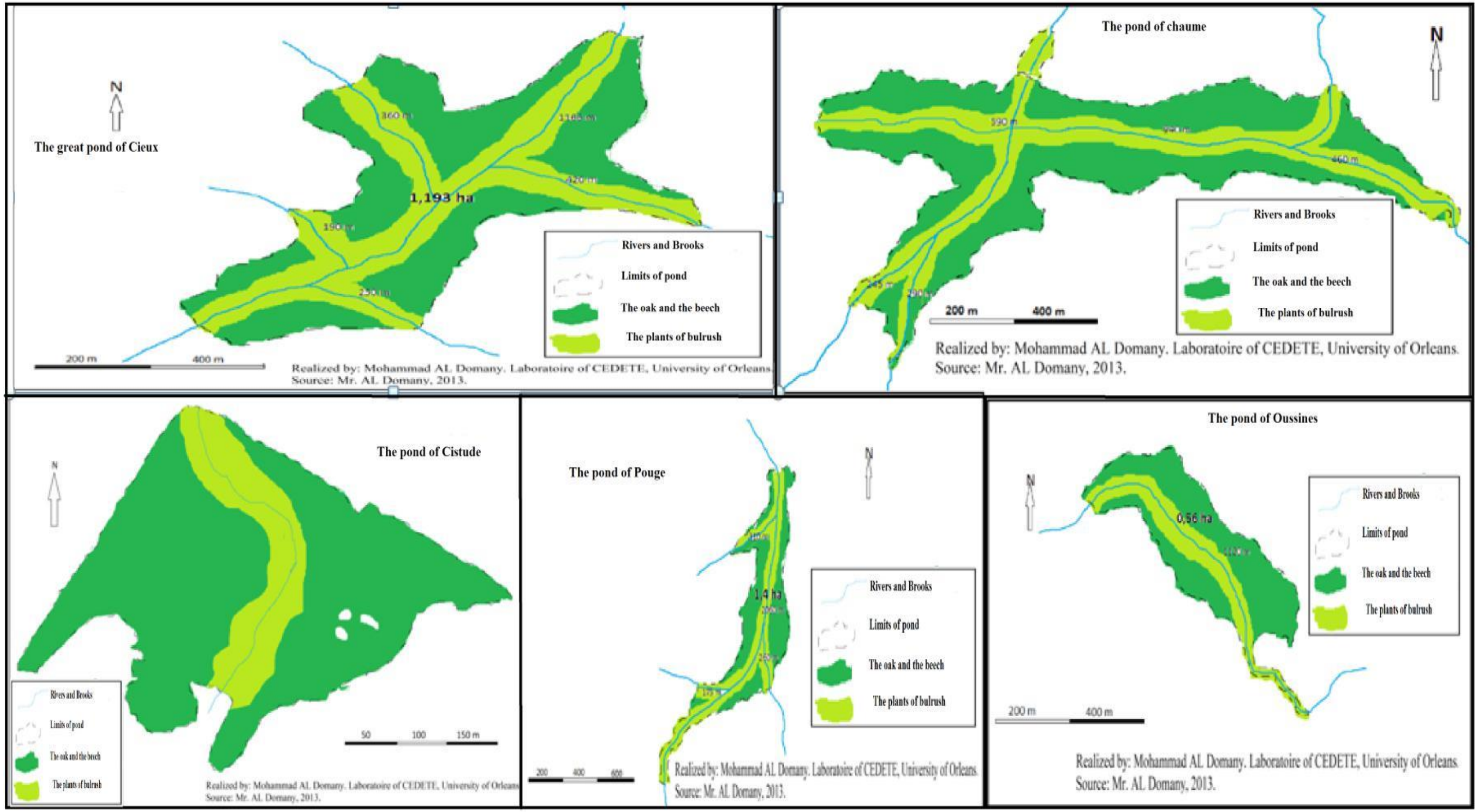

Fig. 3 The maps of potential vegetation in the five ponds

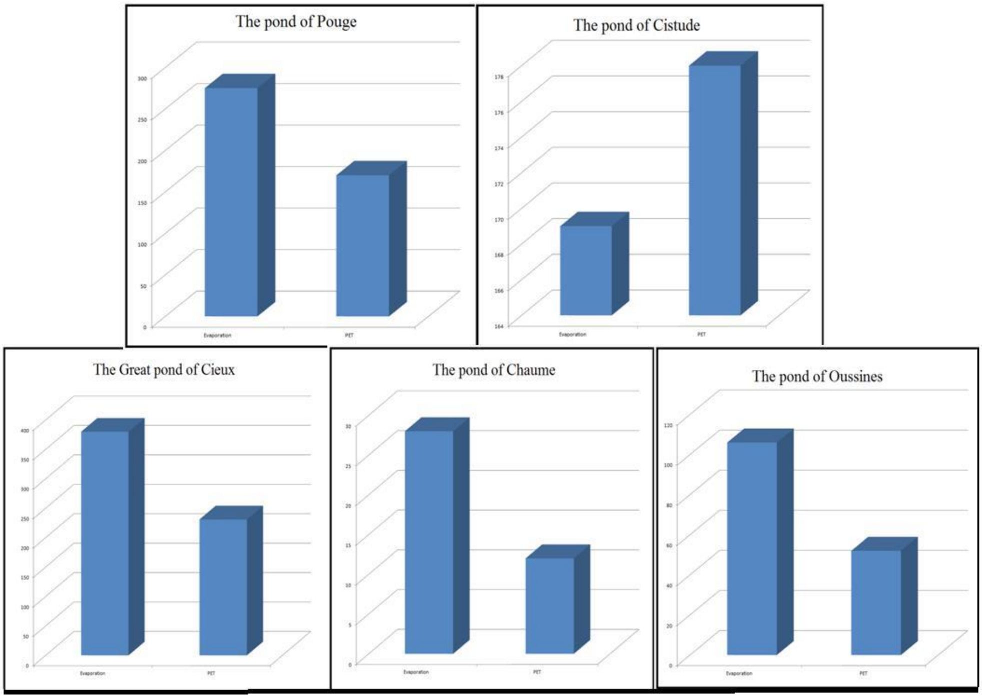

Fig. 4 Comparative histograms of evaporation on ponds and evapo-transpiration on the same territories without pond.

The answer is of course not, because as we know, if the pond exists, all precipitations enter directly into the water balance, but this is not the case if the pond does not exist because part of the precipitation will never arrive on the surface. So it does not enter the water balance. The variability of the interception under forest cover is largely dependent on the importance of the incident precipitation. The interception rate is high for very weak precipitations, and decreases when the rainfall becomes more pronounced. For episodes of low daily intensity (a rain less than 5 mm), interception may exceed 50%, regardless of the tree considered (Aussenac, 1981; Petit et Kalombo, 1984; Nizinski et Saugier, 1988; Gash et al., 1995). The interception then drops rapidly when the rainfalls become more pronounced (from 15 mm) to 10% in the beech-fir, and about 20% in spruce (Dumas, 2008). Other studies say this part ranged between 15 to 35 % of rainfall (Rahmanov, 1962) and some research estimated the interception by vegetation can get to 60% of the precipitation (Perrin, 2011, p7.)

For that, we recalculated the rate of ETP by adding 20% of the precipitation, and these are the results we have obtained: 450 mm on the Great Cieux Pond from 22nd October 2000 to 27th July 2001, 253 mm on the Pouge Pond from 13th April 2000 to 4th September 2000, 94 mm on the

Oussines Pond from 22nd April 2002 to 19th June 2002, 19 mm on the Chaume Pond from 5th October 2007 to 13th November 2007 and 217 mm on the Cistude Pond from 13th August 2013 to 29th October 2013.

Comparing these results with the evaporation rates we obtained in the first case, we found that the amount of water loss is lower if the ponds do not exist.

Finally, to answer the question, Ponds and water resources, a positive or negative balance ? we only need to compare between precipitation and evaporation rates in each of these ponds. Rainfall Amounts are: 1100 mm from 22nd October 2000 to 27th July 2001, 417 mm from 13th April 2000 to 4th September 2000, 206 mm from 22nd April 2002 to 19th June 2002, 33 mm from 5th October 2007 to 13th November 2007 and 193 mm from 13th August 2013 to 29th October 2013.

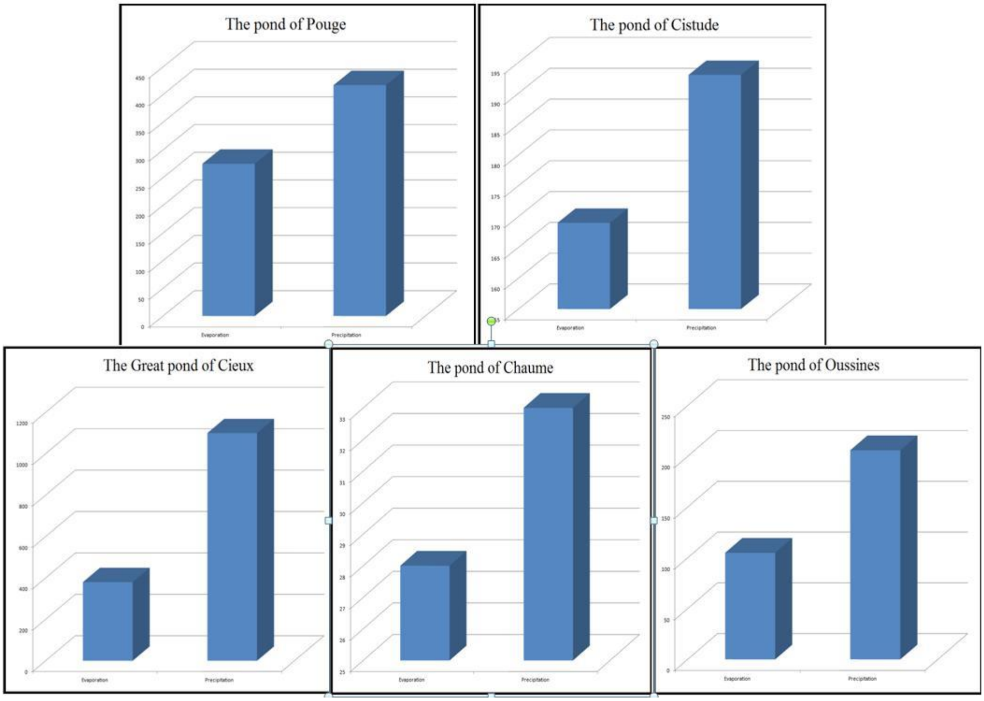

Fig. 5 Comparative histograms of evaporation and precipitations on ponds

These histograms clearly show that rainfall is always higher than the evaporation across the pond. So we can say that the ponds are sources of water gain and not the reverse.

CONCLUSIONS

This research on evaporation in the ponds of Midwest of France brought some novelties in methodology and in terrain of study, in particular the replacement of the air temperature by the water temperature in the formula of Penman-Monteith, the accumulation of different measures of evaporation in site, the consideration of small artificial water bodies, i.e. the ponds (and not the lakes) and their localization in a temperate climate region.

Our initial results tend to indicate that the assertion of local actors that evaporation ponds in the Central West of France is a huge water loss is disqualified and perhaps reverse.

The climate balance (direct precipitation - evaporation) does not seem so far from equilibrium and simulations carried to calculate the balance at the same place in absence of pond show that the presence of a pond works in two directions, one being the increase in contributions by direct precipitation.

The continuation of this research is necessary to lengthen the seasons measures and include a full annual cycle, placing instruments of additional measures, particularly a Class A pan in addition to the floating pan, taking into account all the factors of the water balance, including input and output flows, as well as infiltration and groundwater flows.

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