

FINAL DEGREE PROJECT

Physic-chemical characterization of two benthic transects in Baños and Sabocos tarns (Alto Gallego, Huesca): bathymetric and distance to the runoff source variability analyses

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Abstract

Pyrenean tarns, (*i.e.*, glacier cirque lakes dubbed "*ibones*" in Aragón) have a relevant scientific and social interest and value. Although there have been a few sporadic efforts to understand the main physic-chemical characteristics of their water masses and the concomitant environmental condition, systematic study of their basins and benthic sediments has not been addressed, despite of its interest for the environmental research of these ecosystems.

This study analyzes for the first time the physic-chemical and pedological properties of a 100 m transects spanning from the shore to the maximum depth oftarns of the Aragonian Pyrenees, Baños and Sabocos, both located in the Alto Gállego region (Huesca) to investigate the influence in the composition and variability of sediment due to depth and distance to the runoff source.

Data obtained in this study highlight the importance of lithology and input area have on the physicochemical properties of sediments from the studied tarns. It was found direct relationship between the bathymetry and the variation of their values and concentrations in seven of the analyzed variables.

Have been found clear signs of the effects that human action in one of the studied tarns. Baños tarn shows extremely high values of organic matter and phosphorus due to the discharges draining into its basin, this highlights the necessity of the continue the effort to protect these ecosystems.

Key-words: tarn, *ibón*, glacier lake, Aragonian Pyrenees, subaquatic sediment, benthic transect, bathymetric profile.

Resumen

Los lagos de circo glaciar, o ibones, del Pirineo Aragonés vienen siendo estudiados debido a su gran interés científico y social. Aunque se han realizado muchos esfuerzos por conocer las características de sus aguas y el estado ambiental de los mismos, el estudio sistemático de los sedimentos bentónicos de sus cuencas no ha sido abordado, a pesar del interés que tiene su conocimiento y clasificación para la investigación ambiental de estos ecosistemas.

Uniendo pues la importancia del conocimiento de las características ambientales de los ibones y la importancia a nivel científico de los sedimentos bentónicos, en el presente estudio se caracterizan por primera vez las propiedades fisicoquímicas y edáficas más relevantes de dos ibones característicos del Pirineo Aragonés, Baños y Sabocos, ambos situados en el Alto Gállego. La realización de un transecto de 100 m de longitud que abarca desde la orilla hasta la máxima profundidad de cada ibón permite analizar el

influjo que tanto la profundidad como la lejanía al área de aportes tiene en la composición y variabilidad de sus sedimentos.

Los datos obtenidos en este estudio ponen de manifiesto la importancia que la litología y el área de aportes tienen sobre las propiedades fisicoquímicas de los sedimentos de los ibones. Se ha constatado en siete de las variables analizadas la relación directa entre la batimetría y la variación de sus valores y concentraciones.

Se han encontrado claros signos de los efectos que produce la acción antrópica sobre uno de los ibones estudiados. El ibón de Baños muestra valores extremadamente altos de materia orgánica y fósforo debido a los vertidos que vierten en su cuenca, esto pone de manifiesto la necesidad de continuar con el esfuerzo de protección de estos ecosistemas.

Palabras clave: lago de circo glaciar, ibón, Pirineo Aragonés, sedimentos subacuáticos, transecto bentónico, perfil batimétrico.

1. Introduction

Sediments are heterometric rock and mineral fragments, caused by erosion and meteoric agents, transported, deposited or precipitated in basins as unconsolidated material (Prothero and Schwab, 2004). Underwater sediments were studied and proposed as "underwater soils" for the first time by Kubiena (1953). There has been a long controversy in the scientific community between those who argue that the upper limit of a soil should be the atmosphere (*e.g.*, Foth, 1978), and those who consider also water as a possible soil upper limit, thus extending the edaphic realm to underwater soils (*e.g.*, Kubiena, 1953; Demas *et al*, 1996.).

US Department of Agriculture (USDA) "Soil Taxonomy" first edition, published in 1975, stated in its soil definition that a soil should be able to support vegetation and have horizon differentiation due to pedogenic processes, thus excluding underwater sediments as true soils (Soil Survey Staff, 1975).

Subsequently, some researchers proposed to include underwater sediment in soils classification (*e.g.*, Demas *et al*, 2001. Erich, 2010). They supported their proposal with studies that analyzed different pedogenic processes that take place in underwater environments (*cf.*, Demas *et al.*, 1999; Bradley *et al.*, 2003). Consequently, in the latest edition of the USDA "Soil Taxonomy" suborders *Wassents* and *Wassists* for underwater *Histosols* and *Entisols* were included (Soil Survey Staff, 2010). Currently does not exist a standardized or universal soil definition that has been accepted by the scientific community, in fact scientists continue doing new proposals, thus continue appearing new definitions (*e.g.*, Balduff, 2007; Johnson, 1998; Certini and Ugolini, 2013).

In addition to the studies of (Demas *and* Rabenhorst, 2001), other researchers have conducted pedogenic studies of coastal benthic sediments, highlighting the importance of their knowledge and classification (*e.g.*, Bradley *et al.*, 2003; Miyamoto, 2005; Balduff, 2007, Erich, 2010).

The term "*ibón*" is used in Aragón to designate the glacier cirque lakes, or tarns, existing in the Aragonese Pyrenees, originated by the ice masses dynamics during the last Pleistocene glaciation pulses (*cf.*, Rodriguez *et al.*, 2009; Arruebo *et al.*, 2009, 2013; Arruebo, 2014).

The ecological and environmental value of Pyrenean tarns, along with their scientific interest, recovery rate to anthropic impacts and their sustainable regulation is justified by multiple scientific and social aspects (*cf.*, Rodriguez *et al.*, 2009, Arruebo, 2014). All those aspects have stirred the interest of the scientific community for a deeper knowledge of these high mountain aquatic

ecosystems, becoming also evident the need of their active protection and regulation (Arruebo et al, 2007, 2013, Pardo et al, 2010).

Scientific studies in the glacier lakes encompass different disciplines and objectives, such as: morphometric analysis to achieve the characterization of geometric glacial forms to further understand the formation processes of cirque glacier lakes (e.g., Gil, 2009); Al, Fe, Ti, Mn, Pb, Cd, Zn, Ni, Cu and As, hydrochemical analyses with the aim of elucidate anthropic airborne pollution vectors to these lakes (e.g., Bacardit, 2011). The aquatic fauna and fishing management of high mountain lakes has been also studied to determinate de presence of invasive species and their ecological effects (e.g., Miro et al., 2013). There are also studies about vegetation and microbial life and about the importance of the changing irradiance (e.g., Catalan et al., 2006).

Joining the increasing interest in the study of Pyrenean tarns, with the progress in the study of subaquatic sediments in Soil Science, we propose to study for the first time the most relevant physicochemical soil properties of two characteristic tarns in the Aragonese Pyrenees, Baños and Sabocos, located in the Alto Gallego region of Huesca province. Seasonal environmental analyses of Sabocos and Baños watermasses have been continuously studied from 2002 to 2014, producing a decade spanning high resolution dataset (*cf.* Rodriguez *et al.*, 2009; Arruebo, 2014). Thus, conducting a benthic transect in each of the selected tarns, covering from the shoreline to their maximum depths, will allow to characterize and compare for the first time the influence that both depth and distance to the input area have in the composition and distribution of sediments and chemical compounds, and their influence in the water body and the communities that inhabit it.

1.1. Objectives

Hence, the main objective of this work is the pedological characterization of a 100 m long benthic transect in the mountain lakes of Baños (D max. 14m) and Sabocos (D max. 25m).

To achieve our goal, several specific objectives were proposed:

- Obtain a bathymetric profile, to analyze how depth influences soil properties.
- Conduct a comparative analysis between the two mountain lakes to investigate the influence of bathymetry, distance from direct or diffuse input areas, basin lithology and the effects of anthropic uses and impacts.

2. Study areas location

Two tarns (Sabocos and Baños) with contrasting ecological and geological features despite their proximity, approximately 7,440 m (SITAR, 2014), and different anthropogenic pressure were selected for this study (Figure 1).

It is important to stress the different basin lithologies of both tarns, just about 8 km away, located in the high valleys of Panticosa and points of the headwaters of Gallego and Aguas Limpias rivers. Thus Baños has more acidic soils in its cachement area due to the granitic composition whereas in Sabocos basin dominate limestone dolomite and slates,. (Montserrat and Marti, 2006; Arruebo, 2014).

In the Valley of Tena much of the precipitation is as snow and often persists into late summer in the highest mountains. Snow shelters in winter and plants revive when the nival layer melts: April (1300-1600 m), May (1500-1800 m), June (1700-2400 m) and July-August (2400-3000 m) according to winter accumulations and sunny-shady areas (Del Valle and Rodriguez, 2004).

The annual average temperature is 6.5°C. The coldest months are January and February with 0.1°C (with minimums of -5°C), and the warmest July with 14.9°C (AEMET, 2014).

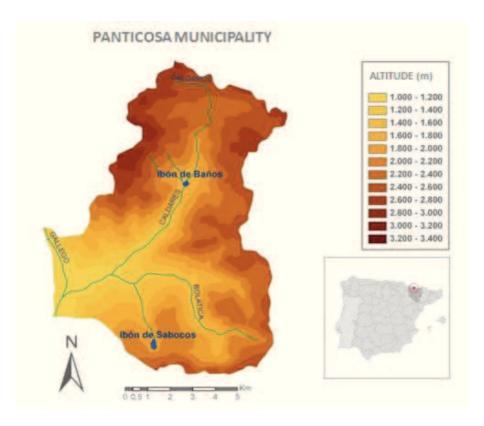


Figure 1: Geographical location of the municipality of Panticosa and the altitudinal map of Sabocos and Baños tarns. Source: modified from Arruebo, 2014.

2.1. Sabocos tarn

The Sabocos tarn is located in a glacier cirque surrounded by Verde's Peak (2,295 m) and the Peña Sabocos massif (2,757 m) located on the north face of the Tendeñera mountain range. This 9.4 Ha tarn is situated in the axial zone of the Pyrenees mountain range at an altitude of 1905 m at the Tena Valley, province of Huesca (Aragón, Spain; Fig. 2; Universal Transversal Mercator - UTM-, Zone 30, European Datum -ED- 1950, coordinates: 724.800 - 4.730.500; Cabrero, 1999). Its biogeographical location corresponds to the High Pyrenean subsector, Central Pyrenean sector, Pyrenean province at the Eurosiberian region (Rivas Martínez *et al.*, 1991).

Sabocos can be reached through two different dust tracks that start at the villages of Panticosa and Hoz de Jaca, crossing along the Panticosa Ski Resort. Sabocos is found close to the SE ski resort limits (Arruebo, 2014; Pardo, 2014). Since their facilities are operating also during the summer season, a number of skiers and mountaineers approach the lake shore throughout the year. In summer, pasturing of bovine and equine cattle is another common activity on the lake waterfront and nearby meadows. Due to historical fish stocking, recreational fishing is also a reported summer activity. No urban sewage or agricultural practices take place in the lake proximities (Arruebo et al., 2009; Lanaja et al., 2008; Santolaria et al., 2014).

Sabocos basin is located on sedimentary rocks that, depending on their nature, can differentiate into three units (Valero, 1974; Wensink, 1962).

The first unit consists of a range of shales and limestones dating from the Lower Devonian, and covering the NW shore of the lake to its mouth and a proximal mountain refuge located in the N (Rivers Aragües *et al.*, 1989, Rodriguez *et al.*, 2009).

The second consists of a range of black pleated limestones usually dated at Emsian or longer in the middle Devonian. These limestones extend over the SW shore of the lake, are consistent with the previous unit and in this area are reversed (Rivers Aragües *et al.*, 1989, Rodriguez *et al.*, 2009).

The third is composed of a large amount of hillside Quaternary debris covering the entire E shore of the lake. This cover is originated by thaw-frost processes typical of high mountain extreme weather conditions, through the Pleistocene-Holocene epoch, and is composed of large number of unconsolidated rock fragments, mostly limestone and dolomite (Rivers Aragües *et al.*, 1989, Rodriguez *et al.*, 2009).

From a geomorphological point of view, Sabocos is located in a well-developed glacial cirque. The slopes S and E are of greater importance, dominated by a range of screes and its present cones of dejection in the lower part that are their

main source of sediment. Above them a strong escarpment which clearly defines the area of directs contributions. Furthermore, the NE side has fewer slopes and contains a dejection cone that also covers the lakeshore. And finally, the slope N shows almost no relief and is what allows the direct drainage downstream (Arruebo, 2014).

The Pyrenees is located just in the transitional zone between the temperate and tropical climate domains. As a result, a temperate dynamics prevails from October to May, while a tropical weather is dominant in July and August. Consequently, winter is dominated by a westerly circulation, with wet and cold winds, and Atlantic squalls. In contrast, during the summer, the North Atlantic (subtropical) Anticyclone, or Azores High, causes warm temperatures and atmospheric stability in the Pyrenees. Spring and autumn are affected by both circulation systems, resulting in a turbulent and non-easily predictable weather pattern (Santolaria *et al.*, 2014)

Situated at an altitude above the subalpine level, its waterfront has relatively poorly vegetated soils. Northern and eastern shores are covered with alpine meadows, whereas in the southern and western shores, where glacier cirque slope is steeper, soils are less developed and mainly covered with rock debris. The lack of deep soils supports no other species than high mountain grasses like *Festuca escoparia*, *Festuca skia*, *Campanula scheuzeri*, *Nardus stricta* or *Trifolium alpinum* (Losa and Montserrat, 1947). Thus, soil cover is about 50 % of the Sabocos tarn catchment area. Littoral submerged macrophytes (e.g., *Callitriche palustris*, *Juncus bulbosus*, and *Sparganium angustifolium*) cover the benthos from the shoreline to a depth of about 6 m from late spring to late summer (Arruebo, 2014).

Sabocos maximum depth is 25 m (Arruebo, 2014; Pardo 2014), and can be reached at about 100 m distance from its E shore in some places (Figure 2).



Figure 2: Ortho-photograph and bathymetric profile of Sabocos tarn. Source: Arruebo, 2014. Santolaria, *et al*, 2014.

2.2. Baños tarn

Baños tarn is also located in the Tena Valley, 8 km away from the town of Panticosa. It is situated at an altitude of 1637 m (Cabrero, 1999), surrounded by peaks over 3000 m high, such as the Gamo Negro, Pondiellos or Argualas.

In the northern part the tarn receives inputs of Caldarés River, by its riverbed converge the waters of the surrounding peaks, going down to the valley as a single course that runs through the town of Panticosa. The mouth is produced few kilometers later, joining the Gallego River in Búbal Reservoir. The tarn has an area of 5.2 hectares (Aragón, Spain; Fig. 2; Universal Transversal Mercator - UTM-, Zone 30, European Datum -ED- 1950, coordinates: 726.200 - 4.738.000; Cabrero, 1999).

Due to the easy access to Baños tarn it has been modified and their thermal water springs used by humans since Roman times as dated by a Roman ace coins depicting emperor Tiberius (14-37 A.D.) and an ace from the Caesaragusta mint depicting emperor Augustus (27 B.C. -17 A.D.; Rodríguez *et al.*, 2009). One of the thermal springs at Panticosa, the Tiberio thermal spring, reaches the highest spring temperature of the Iberian Peninsula (51 °C; GEA, 2010).

From middle of the XIX century the interest for its thermal waters increased and thus began the construction of a thermal complex which radically changed the tarn environment. During the last decade it remains in a long process of hotel conditioning for tourist and recreational use, still not concluded due to the economic downturn (Monserrat, 2009).

From a geological point of view, Baños has a very different nature. It sits on granitic materials, specifically on Panticosa granite massif, which forms a subcircular structure exposed in an area of about 40 km² (García-López *et al.*, 1990). Thus, it is situated on the two igneous materials with most felsic nature of the Panticosa granites range, thus corresponding to the core of the pluton.

The first is a monzonite granite, felsic purely nature and phaneritic medium grain texture. Featuring minerals tipically of that rocks such as oligoclase plagioclase type, microcline feldspar type, and sporadic presence of biotite (Aragües Rios *et al.*, 1989).

The second lithology is a fine-grained granodiorite. It has a greenish tonality that usually betrays a greater presence of mafic materials, namely hornoblenda and biotite, along with the usual plagioclase (oligoclase and andesine) and microcline feldspar type. Towards the more distal areas increases both the content of hornoblenda as the crystals size of this mineral (Aragües Rios *et al.*, 1989, Rodriguez *et al.*, 2009).

From a geomorphological point of view Baños tarn has lost its original morphology due to heavy road and dam construction on the lake shore., The lake has two main surface water inputs: Caldarés and Argualas rivers, that transport a significant amount of sediment to the lake basin. The base of this circus is strongly modified due to the presence of a large hotel complex. There have been important anthropic modifications in the natural environment changing the original lake catchment.

Baños tarn is situated in the subalpine bioclimatic developed between 1,600 m and 2,400 m. In the environment near the lake, is noted as the arboreal vegetation consists predominantly of black pine (*Pinus uncinata*). These formations are intermingled whit scree areas, dominant on the eastern shore of the lake. As altitude increases, the tree formations begin to be replaced by tall grass to reach areas of rocky desert.

Regarding the bathymetry, the deepest point of the lake is 14 meters. It reaches that deep 100 meters away from the mouth of the river Caldares in the north of the tarn (Figure 3; Arruebo, 2014).

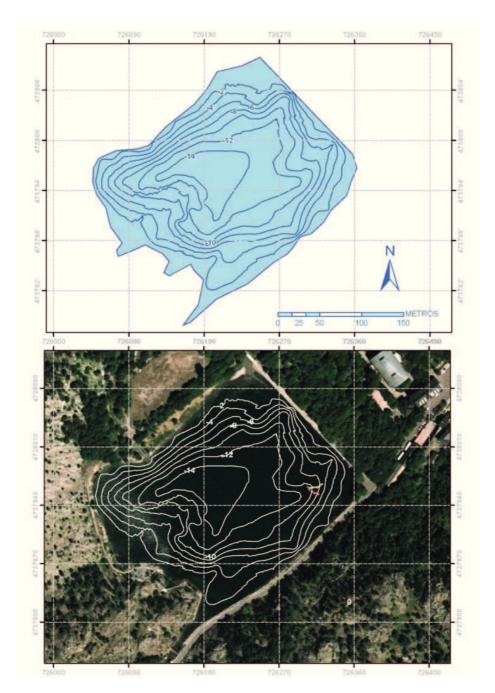


Figure 3: Ortho-photograph and bathymetric profile of Baños tarn. Source: Arruebo, 2014.

3. Methodology

3.1. Sampling

One of the main features of this study is the uniqueness of the studied environment; this is due to the location and difficulty of sampling benthic sediments, which in some cases required direct sampling with depths reaching more than 20 meters. Much of the success of the study is the successful realization of sampling, these are representative and the results are reproducible. For these reasons was designed a specific sampling methodology (Pardo, 2014).

Sampling was carried out on September 21, 2013. Field work was assisted by military divers from the Military Emergency Unit (UME); (Figure 4).



Figure 4: Left, Alfonso Pardo explains the sampling procedure to the scuba-diver team. Right, divers ready to dive in Sabocos tarn. (Photographs: Fernando Navarro)

Underwater sampling strategy is thoroughly described in Pardo (2014). Divers took 10 1 kg samples of surface sediment (from 0 cm to 15 cm) along the marked benthic transect. Sampling spots were selected based on the benthos depth and distance to shore (Figure 5).

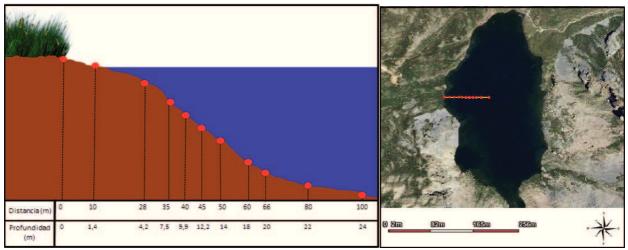


Figure 5: Left, the outline of the points where the samples were collected in Sabocos tarn and depth. Right, image of the sampling transect in Sabocos tarn. (Author: Fernando Navarro)

The same sampling protocol (cf. Pardo, 2014) was deployed in the two studied tarns (Figures 5 and 6).

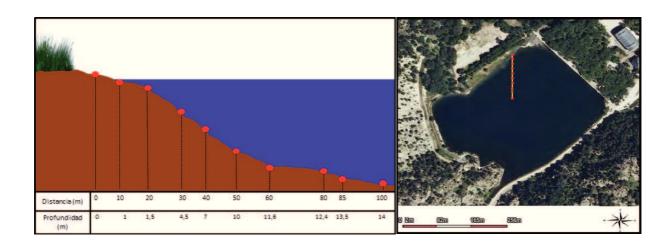


Figure 6: Left, the outline of the points where the samples were collected in Baños tarn and depth. Right, image of the sampling transect in Baños tarn. (Author: Fernando Navarro)

3.2. Laboratory Analyses

The analytical methodology used follows the procedures stipulated by the Environmental Laboratory of the Government of Aragón (DOC-SUE-01) based on presets official methods of analysis (MAPA, 1994). Also the methodology required for each type of analysis to obtain the correct parameters determined (Porta *et al.*, 1986).

Sample preparation

Once the samples arrive at the laboratory, each one is identified and coded with a specific unique reference. Thereafter samples require a pre-treatment for the different analyses. Sample preparation consists in homogenization, drying and disintegration to representative aliquots. Each sample was dried in a stove below 40°C for one week, sieved in a soils mill (UNE 103 100) to a size less than 2 mm.

Coarse Elements

Percentage of coarse elements is calculated by dividing the weight of particles >2mm with the total weight of the dry sample (coarse elements + particles < 2mm). The result is expressed as percentage of air-dry weight (wt %).

Texture

Texture analysis yields the granulometric composition of a sample (*i.e.*, particles size distribution expressed in weight %; Gee *et al.*, 2002), according to the US Department of Agriculture (USDA) textural classification, where:

- Clay (particles up to 2 μm)
- Fine Slime (particles 2-20 µm)
- Coarse Slime (particles 20-50 µm)
- Sand (particles 50-200 µm)

The technique is based on Stokes Law, (Batchelor, 2000) as described herein:

A 10 g sample aliquot is dispersed in a sodium polyphosphate (NaPO $_3$) $_n$) solution, for 30 minutes, to disaggregate the sediment in individual particles.

Later, the solution is sieved through a sieve of 100 μ m. The collected particles are separated in a capsule, dried in a stove (< 40°C), and weighed.

The remaining sieved sample is introduced into the particle analysis equipment and "Sedigraph III" program, to obtain the values for fractions from 0.1 to 100 μ m.

Sand fraction comprises the values given by the equipment heavy particles above the upper 100 microns.

Texture results are plotted in a "texture triangle" (Soil Survey Staff, 2014).

pН

pH is measured in an soil: water 1:2.5 aqueous suspension. Thus, a 30 g sample aliquot is poured in 75 ml of distilled water, stirring it for 15 min, and letting it stand for 30 min.

Later, pH is measured with a pH meter (resolution 0.01 pH units).

Salinity

Soil salinity determined by measuring electric conductivity in a soil solution. Following the official method approved by the Ministry of Agriculture for Order 05/12/1975, for approving as official the analysis methods of soil and water, published in the BOE 31/03/1976, salinity determination requires an extract of a fixed ratio of soil: water, usually 1:5 that has to be indicated in the expression of the results.

An extract of each sample is prepared by, adding a sample aliquot of 8 to 40 ml of distilled water, and mechanically stirred for 30 min. Later, the solution is transferred to another container using a funnel and Whatman filter paper No. 40. Electric conductivity is measured with a conductivity meter by entering the cell and the temperature sensor in the sample solution. The working range of this equipment is between 0.1 dS/m and 13.0 dS/m on dry air mass.

Organic Matter

- Soil carbon is originated from different sources: Inorganic compounds (carbonates, CO₂, etc.)
- Organic compounds and animal remains more or less transformed plants and products thereof constituting the humus.
- Elemental form (coal, graphite, etc.).

Analysis of the oxidizable fraction includes only organic compounds, and therefore organic carbon. The specific methodology is the following:

A0.4 and 0.5 g sample aliquot is placed in an Erlenmeyer and. 8 ml of 8% potassium dichromate and 15 ml of sulfuric acid are added. For the solutions stands for 30 minutes.

Later, 20 ml of deionized water is added. The solution stands overnight.

Afterwards, the solution is centrifuged for 60 min to separate the solid matter in suspension. Then the sample is ready.

The measurement is made in a spectrophotometer at 590 nm of wavelength. The absorption spectrum of the organic matter reaches its maximum in the ultraviolet range and decreases exponentially towards longer wavelengths.

In this case the data form equipment is the absorbance by comparison with the patterns across the regression line relating concentration with color reading. Since what we are interested in is the organic matter concentration of the sample expressed in g/100g dry air sample, is done a conversion of the results obtained by the equipment in the units that we need (Arrieche *et al.*, 2007).

Phosphorus

In Soils phosphorus can be found both as organic and inorganic form. Organic phosphorus is generally predominant, representing between 25% and 75% of the total phosphorus (TP), depending on the organic matter content. Thus, just a fraction of the total phosphorus can be directly assimilated by plants. The Olsen method (Olsen *et al.*, 1957) determines the P soluble fraction in sodium carbonate:

A 5 g \pm 0.05 g of soil sample aliquot is placed in a glass jar with cap, then50 ml \pm 0.05 ml of 0.5 M NaHCO3 should be added and stirred for about 30 minutes. Filter the sample, shaking the glass jars manually and filtering immediately before through a Whatman filter N°40.

Add 5 ml \pm 0.1ml of sodium bicarbonate 0.5 M with dispenser (prepared above) to each 50 ml volumetric flask.

Add 1 ml Sulfuric acid (8%) 1.5 M. Shake it several times for the elimination of CO2, let stand at least 2 hours to their total elimination.

Add 8 ml \pm 0.1ml of reagent II (Ammonium molybdate + Ascorbic acid) to each flask and let stand at least 20 minutes to develop the color blue.

Add distilled water bringing to volume the flasks of 50 ml, mix it, and introduce into cells of 10 mm thick.

Read it in its ultraviolet absorption at 882 nm (UV absorption equipment capable of measuring the absorbance of 900 nm). Due to the aliquot made, the result must should be corrected by calculations to express the final result in mg/kg of phosphorus.

Potassium and Magnesium

Exchangeable soil cations are moved by extraction with a 1N solution of Ammonium acetate at pH = 7 and the extract is determined by atomic emision spectrophotometry. Potassium was measured by emission at a wavelength of 766.490 nm and magnesium with a wavelength of 382.936 nm. The plasma is Argon and it is the energy input required for the elements of the sample to go over to the excited state.

The equipment is an Emission spectrophotometry ICP with a frequency range of 50-60 Hz, and Argon flow at rated pressure of 12 to 25 I / min.

The previous process for obtaining samples to analyze is the following.

Weigh 2.5 g \pm 0.05 g sample and insert in the measuring tube (except blank tube), and add 50 ml \pm 0.05 ml of buffer solution of Ammonium acetate with the dispenser. Leave to macerate overnight.

Shake 30 minutes and centrifuging for 30 minutes

In the case of "blank", operate exactly the same way, except that no sample is introduced.

Of each pot, take using a pipette 1 ml of the supernatant, pour into a sampler tube and add 9 ml of distilled water. The final step is the measure of each sample.

The ICP interpolates the results against the calibration curve that is expressed in mg/l of the solution to be measured. Therefore we must do the necessary calculations to obtain the result in mg/kg of K and Mg.

Calcium Carbonate

The determination of equivalent calcium carbon in soil, has interest in its diagnostic value of different soil properties: structure, biological activity, blocking nutrients, granulometric analysis, etc.

The presence of carbonate blocks around pH values of 8 or above, especially if it is sodium carbonate.

In acidic medium any species of soil carbonates react evolving carbon dioxide. This reaction is used in detecting its presence and in the quantitative measurement by measuring the CO₂ evolved either by measuring the amount of acid neutralized.

$$CO_3^{=}$$
 + H^{+} \rightarrow CO_2 + H_2O

The technique involves the titration of the residual hydrochloric acid versus NaOH (0.5 N) to pH = 7 (equivalence point) with the understanding that the amount of carbonates present in the stored sample relative to the amount of hydrochloric acid consumed in the reaction. The process done is as follows.

Weighing between 0.4 and approximately 0.5 g of sample in disposable cups in the balance accurately \pm 0.0001g.

About 40 ml of distilled water is added to the liquid. This addition is performed to obtain a sufficient sample volume so that selective electrode can perform its function.

Prepare 0.5 N HCl solution and NaOH 0.5 N.

Addition of HCl in the tritador, the instrument added excess 0.5 N HCl to each sample (10 ml).

The next step is the valoration with NaOH.

After that valuation we obtain the result shown in total concentration of carbonates present in the sample, expressed as calcium carbonate concentration (in g/100 g) of mass air dried.

Microelements (Fe, Cu, Mn, Zn)

Microelements of soil are moved by extraction with DTPA solution at pH = 7.3 and the extract is determined by atomic absorption spectrophotometry. The iron is measured at a wavelength of 248.3 nm, copper at 324.8 nm, manganese at 279.5 nm, and the zinc at 213.9 nm. The process done is as follows.

Weigh 20 g. \pm 0.05 g of soil sample.

Add 40 ml \pm 0.05 ml of buffer solution of EDTA (diethylenetriamine pentaacetic acid) with a dispenser.

Shake for 2 hours.

Filter with funnels and after that with filter paper.

Introduce the filtrate in plastic tubes of more than 10 ml.

Make a blank with 10 ml of EDTA.

Introduce the samples in the equipment (atomic absorption spectrophotometer) and after obtaining the calibration curve for each element, do the measurements.

The atomic absorption equipment interpolates results against the calibration curve which is expressed in mg/l of the solution to be measured, so it is necessary do the calculations to obtain the results in mg/kg of each element.

3.3. Statistical Analyses

Two types of statistical analyses have been performed in this study. The first one consisted of a physic-chemical description of both sample datasets. This allowed comparative analyses of the benthic physic-chemical properties fluctuations of both tarns.

The second one involved the statistical determination of the existence of linear correlations between bathymetry and the different analyzed properties. Statistical calculations were performed by means for R 3.1.0 software using the R commander function.

Descriptive Statistics

Statistical parameters were calculated to describe the data set obtained after the laboratory sample analyses. All analyzed properties are quantitative variables. Firstly the position measurements were calculated, such as mean, median and mode. Then dispersion measures were calculated, such as minimum and maximum, range, variance and standard deviation. Finally form measures such as the skewness coefficient and kurtosis were obtained. The aim of these analyses was to allow a most efficient comparative analyses between the two transects and their specific environmental features.

Linear Correlation

Linear correlation for each dataset was studied to determine the existence of connections between two variables. Taking each property separately and comparing with bathymetry, the linear correlation has been quantified between each of them by the Pearson linear correlation coefficient (r).

For a dataset, the (r) value of this coefficient can take any value between -1 and +1. The (r) value will be positive if there is a direct relationship between the two variables, that is, if both increase simultaneously. Negative values indicate that the variable relation is reversed, that is, when a variable decreases the other increases. A value of +1 or -1 indicates a perfect linear relationship between two variables, while a value of 0 indicates that there is no linear relationship between them (Diaz et al., 2001).

In this way we have checked if properties have statistically linear correlation with the bathymetric profile of the tarn and quantify this relationship for each of them. For our dataset has been determined that we can say both variables are dependent with a significance level of 99% for values of r> 0.7, and with a significance level of 95% for values of r> 0.6.

4. Results

4.1. Analytical Results Sabocos

Analyzed properties have been divided into four groups according to their characteristics and their role in soil characterization.

Coarse elements percentage and carbonate content as CaCO₃ are two properties that affect soil structure. The content of coarse elements and carbonates in the samples of Sabocos tarn is high (Table 1), the maximum content of coarse elements occurs at 40 m, while the minimum corresponds to 10 m distance to the shore line. The dominant sample textures in Sabocos loamy-sandy texture in most near shore samples, whereas loamy textures dominate in samples from 60 m on (USDA). Carbonates reach highest values on the right side of the dataset, taking the minimum at 28 m and the maximum at 80 m.

Table 1: Results of statistical analysis carried out in Sabocos tarn for the ten collected samples. For Coarse elements (%) and Carbonates (%).

	Mean	Minimum	Maximum	σ
Coarse Elements	62.5	41.0	90.0	16.6
Carbonates	26.8	12.0	39.0	10.1

A second parameter cluster groups properties related to soil fertility such as pH, salinity and organic matter. Values for pH are slightly alkaline, showing little variation among samples. Salinity values are quite low, while the organic matter values are high (Table 2). The profile values vary irregularly.

Table 2: Results of statistical analysis carried out in Sabocos tarn for the ten collected samples. For pH values, Salinity (dS/m) and Organic Matter (%).

	Mean	Minimum	Maximum	σ	
рН	7.9	7.6	8.1	0.1	
Salinity	0.4	0.2	0.9	0.2	
Organic Matter	2.8	0.9	3.8	1.0	

The third group includes the macronutrients such as phosphorus, potassium and magnesium. At Sabocos phosphorus content is medium, finding the lowest values in the first 50 m from the shore and the highest in the deeper areas. Potassium content however is low, finding the minimum values at 28 m and 35 m, and the maximum at 100 m. Magnesium content of the samples is medium, presenting the lowest values in the first few meters from the shore, with the minimum value at 28 m, and the highest values in the deeper areas, reaching the maximum value at 66 m (Table 3).

Table 3: Results of statistical analysis carried out in Sabocos tarn for the ten collected samples. For Phosphorus (ppm), Potassium (ppm) and Magnesium (ppm).

	Mean	Minimum	Maximum	σ
Phosphorus	7.5	2.0	11.0	3.6
Potassium	22.0	12.0	46.0	10.9
Magnesium	142.8	96.0	166.0	24.0

The fourth group consists on the micronutrients such as Iron, Copper, Manganese and Zinc. The highest values of iron are found in the central part of the dataset, while for the rest of the variables highest accumulations are found in samples 40 m away from the shore in depths over 10 m (Table 4).

Table 4: Results of statistical analysis carried out in Sabocos tarn for the ten collected samples. For Iron (ppm), Copper (ppm), Manganese (ppm) and Zinc (ppm).

	Mean	Minimum	Maximum	σ
Iron	74.2	42.2	110.4	23.8
Copper	8.5	3.1	12.0	3.11
Manganese	32.9	14	52.0	14
Zinc	4.4	1.8	6.6	1.7

4.2. Analytical Results Baños

Content of coarse elements and carbonates in the samples of this tarn is very low (Table 5), the maximum content of coarse elements is at 10 m from the shore, while the minimum is at 40 m. Textures of the samples are thick, dominates the frank-sandy and sandy textures, in the most inshore samples we find sandy textures and we only find frank textures in samples 85 m away from the input area (United States Department of Agriculture). In the samples of this tarn the carbonate content is virtually nonexistent, and we did not find presence of these carbonates in 7 of the 10 samples analyzed.

Table 5: Results of statistical analysis carried out in Baños tarn for the ten collected samples. For Coarse elements (%) and Carbonates (%).

	Mean	Minimum	Maximum	σ
Coarse Elements	34.7	5.8	74.8	22.5
Carbonates	0.8	0	4.0	1.4

pH value obtained is slightly acid and it varies in different samples. We found pH values above 7 in the nearest samples of the input area, with the maximum value at 10 m. From 20 m the pH becomes acid. The salinity values are very low; we did not find any salinity in 4 of the 10 samples analyzed. The organic matter values are very high, finding the maximum level at 60 m from the shore (Table 6). The different profile values vary irregularly as we can see in the standard deviation values.

Table 6: Results of statistical analysis carried out in Sabocos tarn for the ten collected samples. For pH values, Salinity (dS/m) and Organic Matter (%).

	Mean	Minimum	Maximum	σ
рН	6.9	6.2	8.4	0.7
Salinity	0.1	0	0.4	0.1
Organic Matter	7.6	0.5	14.9	6.0

Studied macronutrients are phosphorus, potassium and magnesium. Phosphorus content of the samples is high, finding the lowest values in the first 20 m from the shore and the highest in the deeper areas with a maximum at the 60 m at 11.6 m deep. Potassium content however is low, finding 0 values in the samples near the shore, and the maximum at 60 m. Magnesium content of the samples is very low, presenting low values inshore, with the minimum value of 0 at 40 m, and the highest values in the deeper areas, reaching the maximum value at 100 m (Table 7).

Table 7: Results of statistical analysis carried out in Sabocos tarn for the ten collected samples for Phosphorus (ppm), Potassium (ppm) and Magnesium (ppm).

	Mean	Minimum	Maximum	σ
Phosphorus	20.6	2.0	45.0	16.6
Potassium	27.0	0	64.0	27.3
Magnesium	41.4	0	110.0	33.7

Micronutrients are Iron, Copper, Manganese and Zinc. Iron values are very high; we find the highest values between 50 m and 80 m away from the input area, which reaches an excessive value at 60 m (Table 8). Copper values are a little low, finding the lower values inshore and the highest at 100 m. Values of Manganese and Zinc are very low at the first meters and increase 60 m away from the input area. All these properties have a high standard variation and we can find values nearly 0 in some samples and very high values in others.

Table 8: Results of statistical analysis carried out in Baños tarn for the ten collected samples for Iron (ppm), Copper (ppm), Manganese (ppm) and Zinc (ppm).

	Mean	Minimum	Maximum	σ
Iron	187.8	23.4	412.0	175.5
Copper	4.1	0.6	9.0	3.2
Manganese	27.1	3.6	57.2	18.8
Zinc	5.9	0.5	10.8	3.4

4.3. Correlation Results Sabocos

The correlation analysis showed positive results for six of the studied variables. Phosphorus and Magnesium values increase with the distance from the input area and the bathymetry (Figures 7, 8). The statistical value obtained for the Pearson correlation coefficient (r) is quite high in both, which notes the influence of these variables on the phosphorus and magnesium content of the sediments samples.

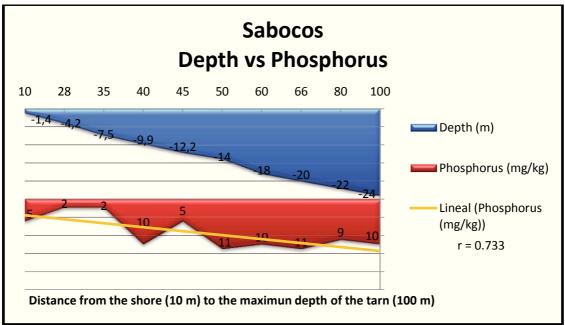


Figure 7: Statistical correlation analysis of phosphorus values, carried out in Sabocos tarn for the ten collected samples. (Author: Fernando Navarro)

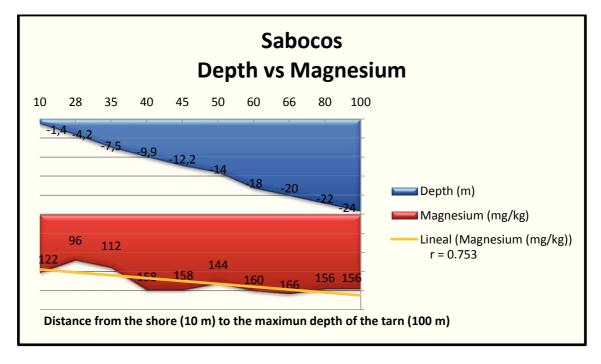


Figure 8: Statistical correlation analysis of magnesium values, carried out in Sabocos tarn for the ten collected samples. (Author: Fernando Navarro)

Carbonates are one of the variables which showed greater linear correlation with bathymetry and distance to the input area (Figure 9). The result of the Pearson correlation coefficient obtained after the statistical analysis was very high (r = 0.916).

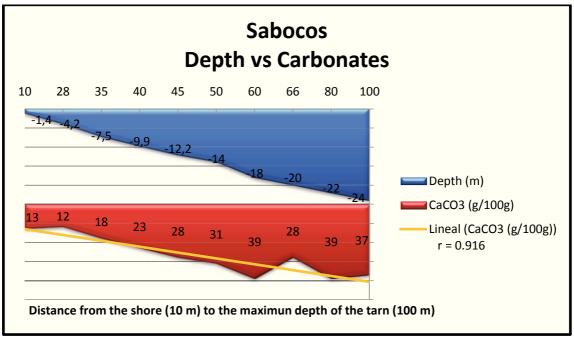


Figure 9: Statistical correlation analysis of carbonates values, carried out in Sabocos tarn for the ten collected samples. (Author: Fernando Navarro)

Copper is one of the three micronutrients which have shown a linear correlation in the statistical study (Figure 10). The results showed a high value of linear correlation coefficient of Pearson (r = 0.751).

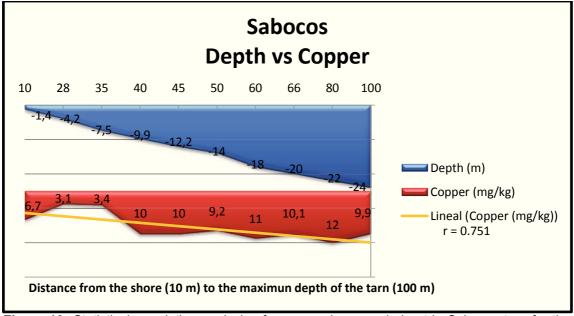


Figure 10: Statistical correlation analysis of copper values, carried out in Sabocos tarn for the ten collected samples. (Author: Fernando Navarro)

Manganese and zinc have shown linear correlation also in relation to the bathymetry and distance to the input area (Figures 11, 12). In this case it has been accepted the statistical value of r > 0.6 as acceptable in the case of manganese, although the value of the sample at 66 m from the shore does not follow the progression, this is corroborated by the rest of the dataset. In the case of zinc the coefficient obtained shows a very high correlation (r = 0.826).

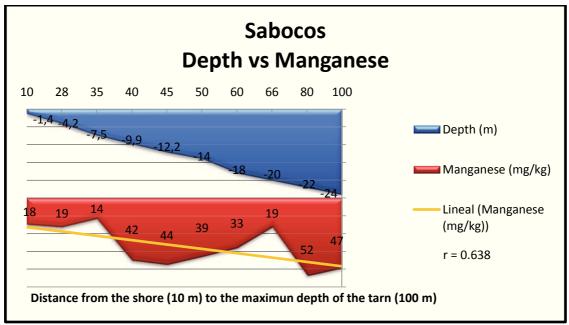


Figure 11: Statistical correlation analysis of manganese values, carried out in Sabocos tarn for the ten collected samples. (Author: Fernando Navarro)

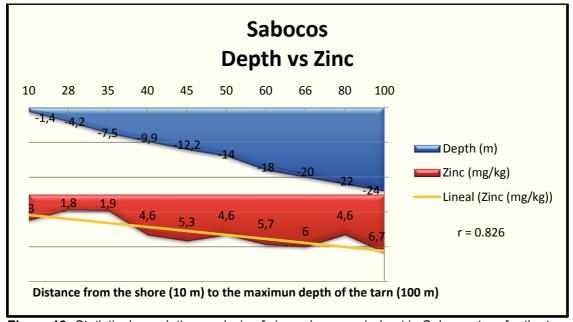


Figure 12: Statistical correlation analysis of zinc values, carried out in Sabocos tarn for the ten collected samples. (Author: Fernando Navarro)

4.4. Correlation Results Baños

The correlation analysis showed positive results for six of the studied variables. Phosphorus and Magnesium values increase with the distance from the input area and the bathymetry (Figures 13, 14). The statistical value obtained for the Pearson correlation coefficient is very high in both, which notes again the influence of these variables on the phosphorus content of the sediments samples.

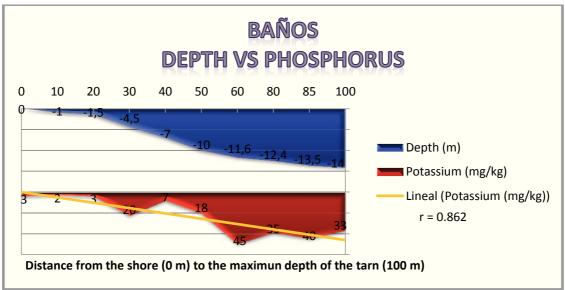


Figure 13: Statistical correlation analysis of phosphorus values, carried out in Baños tarn for the ten collected samples. (Author: Fernando Navarro)

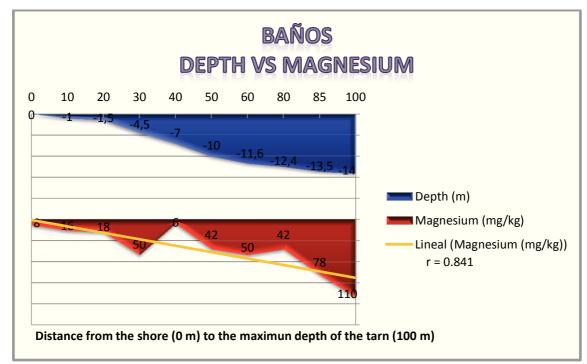


Figure 14: Statistical correlation analysis of magnesium values, carried out in Baños tarn for the ten collected samples. (Author: Fernando Navarro)

Organic Matter in Baños tarn showed linear correlation to the bathymetry and distance to the input area (Figure 15). In this case the linear correlation coefficient of Pearson obtained was not very high (r=0.661), but as the values of r> 0.6 were accepted, therefore this relationship was determined.

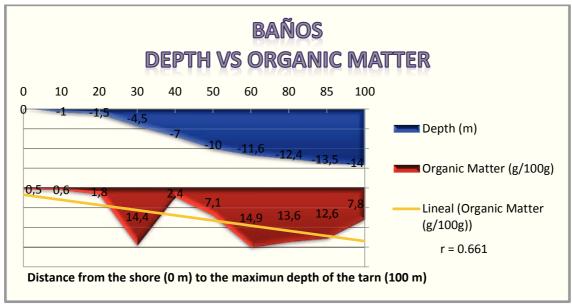


Figure 15: Statistical correlation analysis of organic matter values, carried out in Baños tarn for the ten collected samples. (Author: Fernando Navarro)

Copper is the variable that has shown greater statistical correlation in the studio with a value of r = 0.946. This determines the dependence of this element with the bathymetry and distance to the input area (Figure 16).

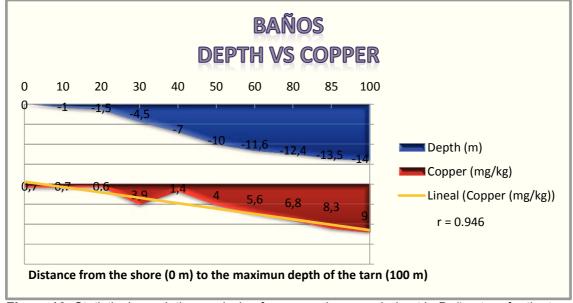


Figure 16: Statistical correlation analysis of copper values, carried out in Baños tarn for the ten collected samples. (Author: Fernando Navarro)

Manganese and Zinc also showed high linear correlation values (Figure 17, 18). These micronutrients showed high accumulation in the deepest area of the tarn, while the lowest values were present near the shore at the mouth of the river.

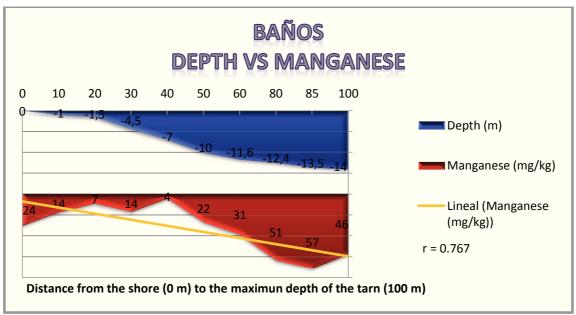


Figure 17: Statistical correlation analysis of manganese values, carried out in Baños tarn for the ten collected samples. (Author: Fernando Navarro)

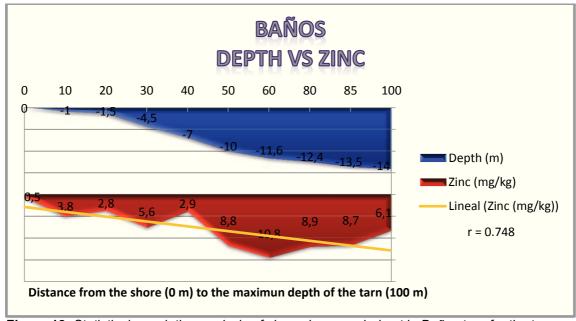


Figure 18: Statistical correlation analysis of zinc values, carried out in Baños tarn for the ten collected samples. (Author: Fernando Navarro)

4.5. Comparative Results

The results obtained for the two studied tarns showed significant differences in several of the analyzed properties (Figure 19). In Sabocos tarn the percentage of coarse elements is almost double that in the Baños tarn. The difference in carbonates values is also very significant because levels of this element in Baños tarn are almost nonexistent.

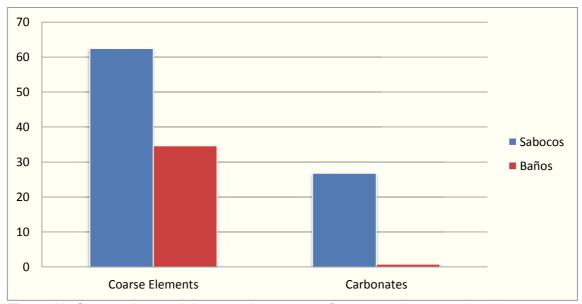


Figure 19: Comparative graph between the two tarns, for coarse elements and carbonates mean values. (Author: Fernando Navarro)

The differences in pH mean that sediments of Sabocos tarn are alkaline and the Baños tarn are acid. Salinity is higher in the ibon Sabocos, and content of organic matter beeing high in both, has extremely high levels in Baños tarn (Figure 20).

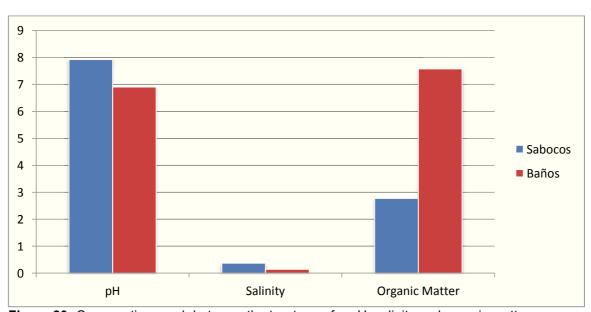


Figure 20: Comparative graph between the two tarns, for pH, salinity and organic matter mean values. (Author: Fernando Navarro)

The levels of phosphorus and potassium obtained are higher in Baños tarn. Stand out the large amount of magnesium (mg / Kg) obtained in samples of Sabocos tarn, being 200% higher than in Baños tarn (Figure 21).

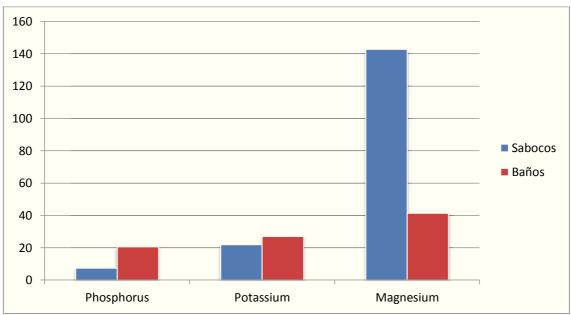


Figure 21: Comparative graph between the two tarns, for phosphorus, potassium and magnesium mean values. (Author: Fernando Navarro)

The microelements studied showed varied results in terms of both tarns. The values obtained for copper and manganese are higher in Sabocos tarn. Moreover levels of iron and zinc are higher in Baños tarn. Stand out the high iron content found in sediment samples of Baños tarn (Figure 22).

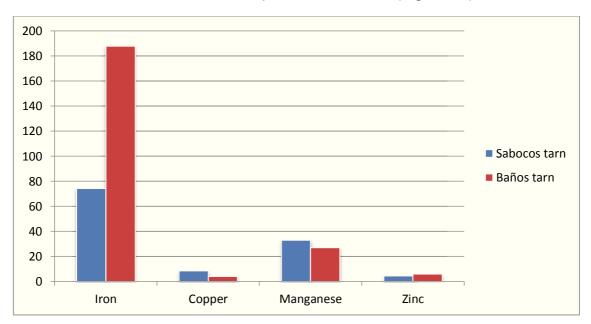


Figure 22: Comparative graph between the two tarns, for iron, copper, manganese and zinc mean values. (Author: Fernando Navarro)

5. Discussion

5.1. Sediments samples characterization

In the characterization of benthic sediments of each tarn, 10 samples were studied for the transept made, and in each of them the values for the 12 studied properties were obtained. To get the value of each of these properties we did the arithmetic mean of all the values of the ten samples. The mean value associated had a great standard deviation and a very high variance. This is because the samples collected corresponded to different parts of a bathymetric profile, so that the conditions associated with each depth were significantly different and existed diverse properties values in the different samples.

The study of the grain size Sabocos tarn showed that it was a sandy loam soil (coarse texture) in the samples near the shore and texture changed to frank (medium texture) in the deepest points of tarn. Obtaining the samples required a complicated sampling, so that the amount of sediment extracted corresponded to the first centimeters of benthic substrate of the tarn, therefore the texture obtained in both was thick and they showed a very high content in coarse elements.

The carbonate content is related to the pH, and the results also show this relationship. The pH obtained in sediments of Sabocos tarn was basic; this is mainly due to the lithology of geological components surrounding this glacial lake. The composition of limestones mainly contributes to the pH obtained in this lake, and at the same time the carbonate content is higher and also increases the salinity of the sediments. The pH obtained in Baños tarn is also slightly acidic due to the lithology surrounding the lake consists on granite and slates, leading to acidification of the benthic substrate of the tarn. The acid pH causes the carbonate content is virtually nonexistent and therefore lower salinity values sediments are also present.

The organic matter content in the sediments of both tarns is very high. For Sabocos tarn, which is surrounded by herbaceous vegetation and in this area there is an intense grazing and wild animal life, this means that when contributions materials produced from the surrounding areas are deposited, they contain large amount organic matter. For Baños tarn, organic matter mainly comes from the activities related with the spa of the tarn, and thus it has a very high content of organic matter. The decomposition of organic matter leads to the decrease of pH as reflected in the acid pH of Baños tarn (Labrador, 1996), although in this case the slightly acid pH in this tarn is mostly due to the lithology of the area, which has granitic nature.

The values for macronutrients show acceptable values of phosphorus in both mountain lakes. The phosphorus content increases as decreases the texture

and increases with organic matter, which is a continuously source of phosphorus to the soil, so that Baños tarn have a higher level of phosphorus. Instead the potassium content is very low, this may be largely due to clay colloidal materials retain this element better than those with coarse textures such as those present in the samples analyzed (Munson, 1985).

The micronutrients studied have been iron, copper, manganese and zinc. These elements are found in the soil in lower quantities as macronutrients like phosphorus or potassium. This does not mean that its concentration in the soil is not important, because the lack or excess of these elements can severely impair soil fertility (Montanes and Heras, 1970). The values obtained for the microelements are quite low except for the case of iron, which shows values in Baños tarn reaching 412 mg / kg. This is an amount that can pose serious problems in the interaction with other soil properties and the surrounding ecosystem (Prochnow et al., 2009).

5.2. Linear correlation

In the analysis of linear correlation we intended to verify the existence of a direct relationship between bathymetry and distance to the input area regarding the various properties and components of benthic sediments of the tarn. The results indeed showed the existence of this relationship for seven of the twelve properties analyzed. An acceptable correlation value for the Pearson correlation coefficient was understood as r> 0.6, and high value of correlation was proposed in the coefficient r> 0.7. Of the twelve properties analyzed in Sabocos tarn six of them presented linear correlation, five of them showed a high linear correlation and only in the case of manganese the value of the statistic showed an acceptable correlation. Properties such as coarse matter, pH, salinity, organic matter, potassium and iron, showed an insufficient value of correlation or the slope of the line obtained was not sufficient to consider the values of these properties increased proportionally as increasing the depth and drove away from the input area.

Of the twelve properties analyzed in Baños tarn, as in Sabocos tarn, five of them had a high level of correlation, and only the organic matter showed an acceptable correlation. In this case the virtually absence of carbonates (carbonates is the property which has shown higher linear correlation in Sabocos tarn), no linear correlation has been determined for carbonates in this tarn. On the other hand, the organic matter had an acceptable linear correlation in Baños tarn in contrast to Sabocos tarn.

Importantly, we have determined the existence of linear correlation for both tarns for the properties of phosphorus, magnesium, copper, manganese and zinc. The fact that the results match both tarns, gives more value to the results.

5.3. Comparative values

The differences between the two tarns are evident when the results for each are analyzed comparatively. There are significant differences in almost all parameters analyzed and this is due to various factors such as bathymetry, input area, lithology and anthropogenic effects.

One of the first significant differences is found in the content of coarse elements present in the samples of each of the mountain lakes studied. Sabocos tarn has a very high percentage of coarse elements in each sample, becoming more pronounced in the deeper areas of the tarn. Moreover the Baños tarn has lower values, because its average depth is lower. Another factor to keep in mind to illustrate this difference is the contribution of rocky materials that exist in each of the mountain lakes in Sabocos these derived from the adjacent mountain systems tarn basin, while in Baños largest source of contributions is trailing material from Caldares river and deposited on the tarn (Rivas Martinez *et al.*, 1991), the diameter and number of these is lower than in the first.

The carbonate content shows a great difference between them, due to the different lithology of them that harbor even when both are next to each other. Sabocos tarn presents more calcareous lithology, as opposed to Baños tarn. The lithological materials of Baños tarn are principally granites and slates from the surrounding landforms (García-López, 1990). This causes the carbonate content of Sabocos tarn is very high, while the presence of those is not found in Baños tarn.

The increased presence of carbonates in the Sabocos tarn makes the pH increases to an alkaline pH while Baños tarn presents values below 7, being acid.

One of the parameters that have most similar values is the salinity; both have a very low content of that. The ecosystems studied are high mountain lakes, and this feature makes the contributions they receive are very scarce in dissolved salts.

Both studied systems also differ in the amount of organic matter present in soil. Baños tarn has a lot of organic matter in the samples analyzed, while Sabocos tarn values for that are lower. This is due to the different activities carried out in the vicinity of both tarns. The strong anthropic action carried out in the vicinity of Baños tarn (Monserrat, 2009) makes contributions of different elements that increase the amount of microorganisms and organic matter of the tarn. Anthropic pressure is also shown in the results for phosphorus, in these Baños tarn shows high values, more than double of Sabocos tarn. These high levels of phosphorus and organic matter arise from discharges that occur from the hotel complex adjacent to the tarn.

The difference in the content of magnesium, which is very high in Sabocos tarn, is directly related to the carbonate content. Of the entire amount of carbonates in the samples analyzed in this tarn, a portion is in carbonate magnesium form, this causes the amount of this element is so high.

Finally, the difference in the concentration of iron shows that there is a lot of this microelement in Bathrooms tarn. This is due to the origin of granitic existing lithological materials in the area of this tarn. The level of this element in Sabocos tarn is more limited.

6. Conclusions

- I. The lithology of the surrounding systems where Sabocos and Baños tarns are located is very different, and this is the most crucial element in terms of the difference many of the parameters results obtained in the analyzes.
- II. The soil characterization of sediments from both tarns showed representative results reflecting the state of these ecosystems and may help in the future to identify potential changes or contamination produced in them.
- III. The bathymetric survey of both tarns has confirmed the existence of a direct relationship between bathymetry and physicochemical properties such as organic matter, phosphorus, magnesium, carbonate content, copper, manganese and zinc. 5 other properties, of the 12 studied, show no relation to the bathymetry.
- IV. The results are related to the ecological conditions of the underwater environment, and detect the consumption of certain nutrients in the shallow area and its accumulation or increased mobility in the area of deeper water.
- V. There have detected evidences of variation due to anthropic action in some properties, such as the level of phosphorus and organic matter, which become very apparent in Baños tarn, much anthropized. Values of both parameters are more than twice of the performed measurements in Sabocos tarn.

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8. Attachments

8.1. Elements without linear correlation

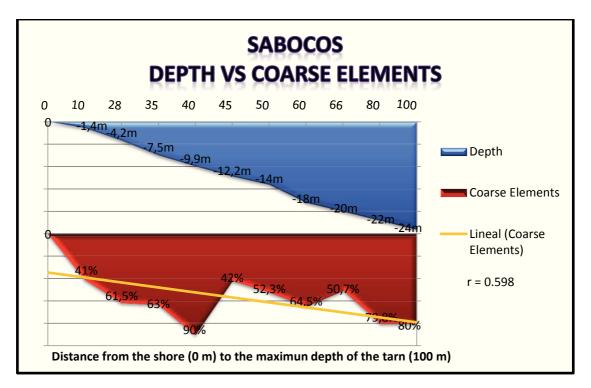


Figure 23: Statistical correlation analysis of coarse elements, carried out in Sabocos tarn for the ten collected samples. (Author: Fernando Navarro)

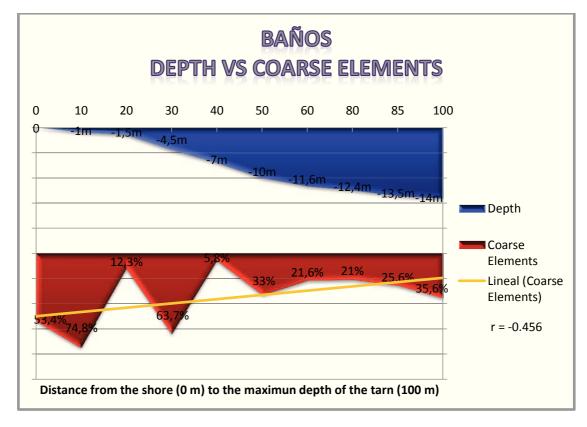


Figure 24: Statistical correlation analysis of coarse elements, carried out in Baños tarn for the ten collected samples. (Author: Fernando Navarro)

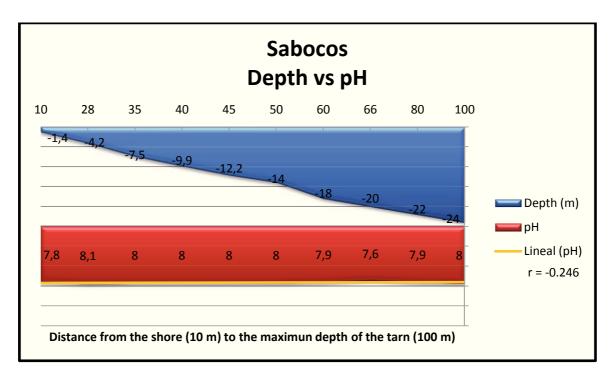


Figure 25: Statistical correlation analysis of pH, carried out in Sabocos tarn for the ten collected samples. (Author: Fernando Navarro)

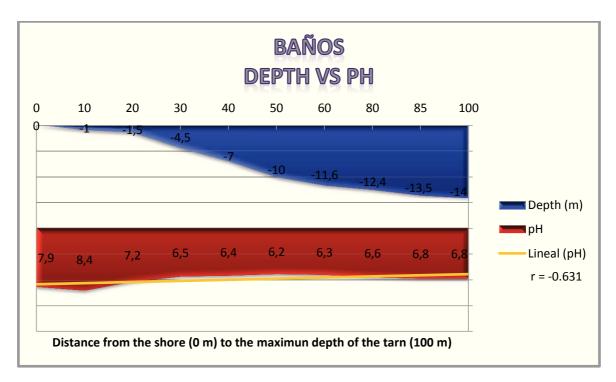


Figure 26: Statistical correlation analysis of pH, carried out in Baños tarn for the ten collected samples. (Author: Fernando Navarro)

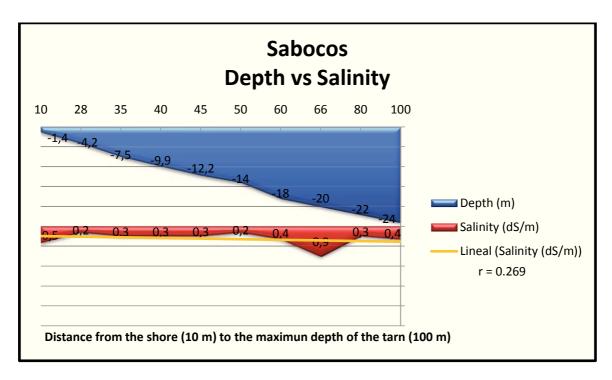


Figure 27: Statistical correlation analysis of salinity, carried out in Sabocos tarn for the ten collected samples. (Author: Fernando Navarro)

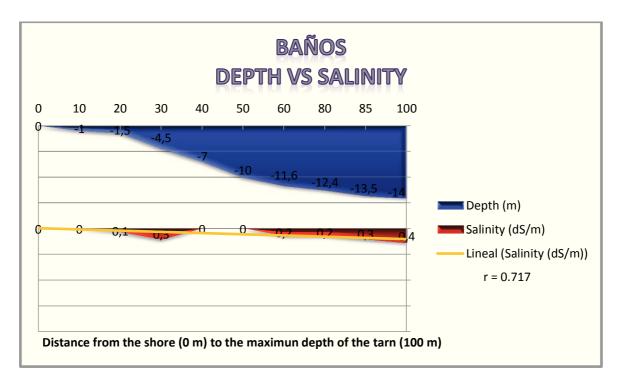


Figure 28: Statistical correlation analysis of salinity, carried out in Baños tarn for the ten collected samples. (Author: Fernando Navarro)

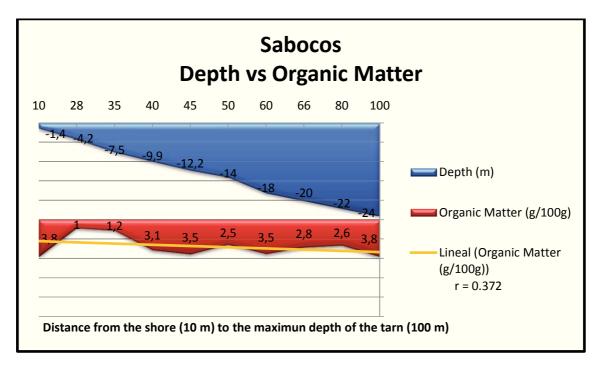


Figure 29: Statistical correlation analysis of organic matter, carried out in Sabocos tarn for the ten collected samples. (Author: Fernando Navarro)

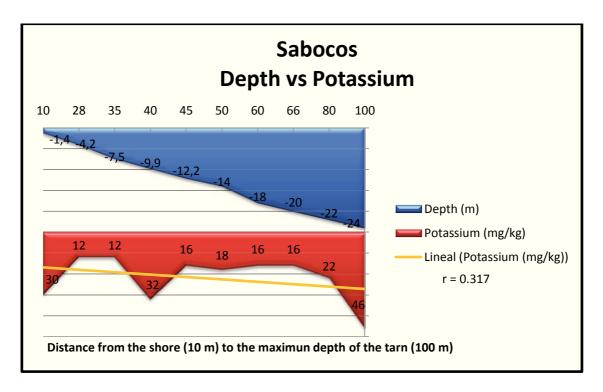


Figure 30: Statistical correlation analysis of potassium, carried out in Sabocos tarn for the ten collected samples. (Author: Fernando Navarro)

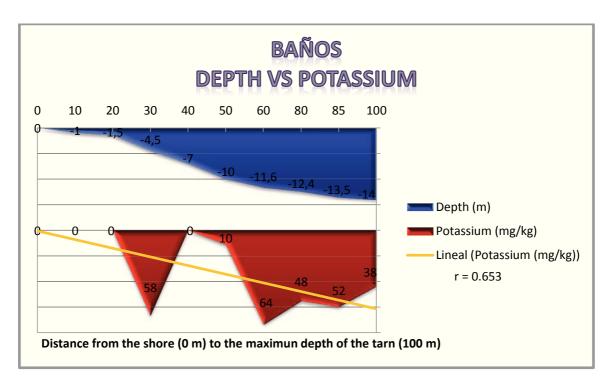


Figure 31: Statistical correlation analysis of potassium, carried out in Baños tarn for the ten collected samples. (Author: Fernando Navarro)

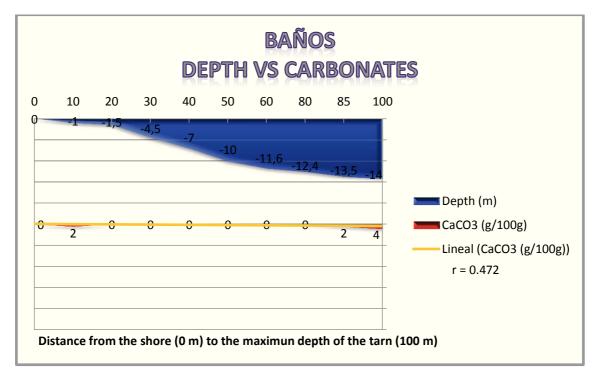


Figure 32: Statistical correlation analysis of carbonates, carried out in Baños tarn for the ten collected samples. (Author: Fernando Navarro)

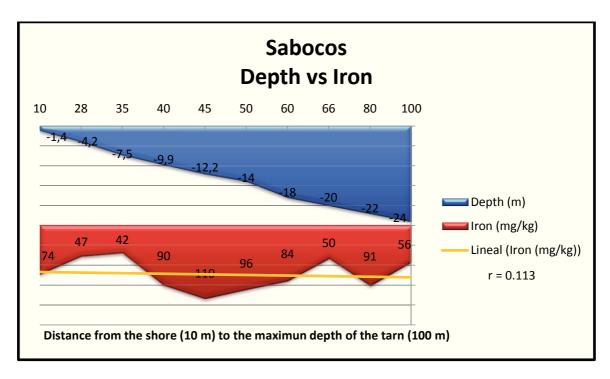


Figure 33: Statistical correlation analysis of iron, carried out in Sabocos tarn for the ten collected samples. (Author: Fernando Navarro)

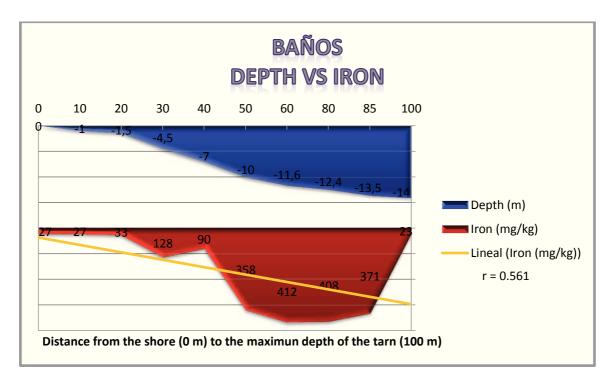


Figure 34: Statistical correlation analysis of iron, carried out in Baños tarn for the ten collected samples. (Author: Fernando Navarro)

8.2. Photographs

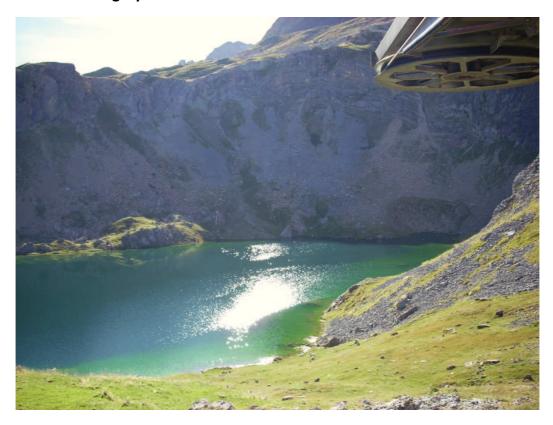


Figure 35: Picture in Sabocos tarn



Figure 36: Picture in Sabocos tarn



Figure 37: Picture in Sabocos tarn



Figure 38: Picture in Sabocos tarn



Figure 39: Picture in Sabocos tarn



Figure 40: Picture in Sabocos tarn



Figure 41: Picture in Baños tarn



Figure 42: Picture in Baños tarn



Figure 43: Picture in Baños tarn



Figure 44: Picture in Baños tarn