Lemna obscura releasing analyze under spectral signature at the Maracaibo´s lake, Venezuela.

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ABSTRACT

The Maracaibo's Lake is a basin located in the western side of Venezuela and supports an important agricultural and industrial activity. This basin is a core of the petroleum industry since the 20th century. Oil activities had develop a ecological disorder, which a sign of primary manifestation were a cultural eutrophication process related to the phytoplankton blooms in the middles 70's, and more recently, since 2004 an extensive covered area of *Lemna obscura* .

It seems that change in the hydrological cycles and input of pollutants are the reasons of this macrophyte appearance. In this research, the spectral signature of *Lemna obscura* is evaluated using MODIS images from 2000 to 2010. Other program as ENVI 4.3 has been considerate to correlate hydrological data with *Lemna obscura* bloom. Spectral signature appearance of *Lemna obscura* could be a consequence and indicates changes in the hydrological and ecological features in Maracaibo´s Lake.

Key words: Maracaibo's Lake, *Lemna obscura,* Spectral signature

INTRODUCTION

Maracaibo´s lake shorelines have been historically, a primary support for the development of human activities as fishery, in which societies have established cities built infrastructure and found a natural resources. These actions have impact environmental cost that it has accelerated and intensified in recent decades (Hernandez et al, 2003).

Maracaibo´s Lake is an estuarine lake surrounded by high agricultural land productivity, and oil industry; responsible for the generation of food and energy resources and seat of a large population. (Aldana et al, 2006). With the onset and development of petroleum activities, coupled with population growth in the basin of Maracaibo´s Lake, significantly pollution problems have been increased. Thus, the waters of Lake have undergone a change in chemical composition from 1938, the date which begins more human intervention to the system due to the activities of oil exploration, agriculture and significant population growth, producing a large amount of waste are discharged into the lake and tributaries, which have dramatically altered the ecological balance maintained in the ecosystem for thousands of years. Beginning in 1956, an increase in salt concentration generated by the opening of the navigation channel, which has turned the waters of lake unacceptable sources for human consumption, irrigation and industrial uses (Bautista, 1997). These pollution problems have led to serious eutrophication events reflected in algae blooms during the late seventies, eighties and nineties, and more recently the emergence of the aquatic plant *Lemna obscura* that has come to cover areas larger than 20% of the lake area.

The causes that fostered for emergence and growth of *Lemna obscura* are not entirely clear, there are various theories about its occurrence, and the scientific community is deeply studying the case, a problem associated with the growth of *Lemna obscura* are the communities living in coastal areas of the lake, as it is in these areas to reach the ground and accumulate presents a decomposition process that generates odors, pests growth, that can affects of the health of these people and damage the quality of life. From 2004 has been observed that these problems are repeated cyclically affecting the welfare of the community, so the problems of *Lemna obscura* outcrop; besides of being a problem of environmental pollution has become a serious social problem.

It is now necessary to establish growth patterns with spatial and temporal distribution of *Lemna obscura* in order to rapidly respond the attack on the symptoms of its development, for which one of the alternatives is the observation and analysis of satellite images of the area, known as remote sensing. Remote sensing is defined as the measurement of electromagnetic radiation reflected, emitted or bounced off the surface of the Earth by instruments located away from the site of interest, usually on board aircraft or space platforms (Sabins, 1986 cited by Benayas 1993).

Remote sensing is to identify and characterize surface materials and processes that take place from electromagnetic radiation from the unit, meaning both issues by the land surface itself as the mirror that comes from sun, to prevail over another depending on the spectral range considered. In general, when solar radiation strikes a material, a part of it is reflected and the rest is spread through it. There, some is absorbed and the rest undergoes a scattering process so that some of the energy emerges from the material scattered in the same area for which entered, adding to the radiation reflected by the material and together with the irradiance to define spectral reflectivity of the same. It is precisely the dependence of the reflectivity with the wavelength, together with the fact that the spectral reflectivity is closely related to the nature of the material that makes possible to recognize materials in remote sensing (Gilabert et al, 1997). It is therefore the different forms of electromagnetic radiation interact with matter in terms of its reflectivity that determines the spectral response of natural surfaces and allows the study.

Remote sensing has provided significant advantages in knowledge, understanding and conservation of natural resources, allowing observing and measuring the properties of a hard sphere covered by other means (Hernández et al, 2003). Remote sensing offers the ability to work ecology with extensive data and synoptic scales. Previous assumptions concerning large-scale problems are mainly extrapolated from estimated results to smaller scales. It now has the opportunity to measure large-scale processes as they really are. It is the only means of observing global issues regular, consistent and synoptic, is also close to the application of computer models that the only possible interpretation of questions on a wide scale. We also have continuous access to data and long time. This allows the study of phenomena that are characterized precisely by this, by the evolution in time (Benayas, 1993).

Remote sensing has shown excellent results in the interpretation of natural phenomena such as hurricanes, fires and dispersion of pollutants. In this vein, the use of remote sensing has allowed precise estimate several parameters related to water, mainly in large oceanic regions, with the temperature and chlorophyll as the elements on which most scientists have focused efforts (Hernández et al; 2003). Remote sensing, especially satellite imagery, is an important source of information for mapping and characterizing land use and landscape structure at regional level. In addition, geostatistics is an appropriate tool for the analysis of the information space (Alperin et al, 2002).

Precisely the interpretation of satellite images is a reliable alternative to determine in the case of Lake Maracaibo, location and extent of *Lemna obscura* and depending on the interpretation of group of pictures that can predict the movement of a given mass of Lake, which can quickly alert the community and agencies to respond effectively, in many cases before arrival at the site of the masses of *Lemna obscura* in order to minimize the negative effects of the appearance of this plant species.

For the proper use of satellite images is necessary to accurately correlate the observed in a given image with what you have in the sampling area; for this research project seeks to establish relationships and values of irradiance reflectance of *Lemna obscura* with data referring to quantity of chlorophyll content, plant growth stage and physical - chemical water of the lake. The adoption of an empirical model, compared with a theoretical required in remote sensing, to establish a numerical relationship between the parameter estimate and the sensor values, from in situ observations, taken at the time of image acquisition. This relationship between the observed parameters of water quality and multispectral data, often addressed through regression analysis. This procedure is most often used by its simplicity and accuracy, and because it implicitly takes into account factors that may influence the relationship between these parameters and multispectral data (Chuvieco, 2002). In this order a first stage is to try to identify in MODIS images a spectral signature of *Lemna obscura* given by the ENVI program, as a prior method to identify the plant in the lake.

This paper refers to a first step when we collects different MODIS images from 2001 to 2010 year period and we selects some of them to try to identify using program ENVI 4.3 appearances of a spectral signature that could be correlated with the moments when *Lemna obscura* appears in the lake; subsequences stages in the investigation going to be looking for several samples in areas with plenty of *Lemna obscura* and with the help of a field spectroradiometer to measure reflectance and irradiance *in situ*, while taking laboratory samples to measure phonological characteristics of the plant in this way could be established correlation and determine the spectral signature of the *Lemna obscura*, and different Vegetation Index; with which afterwards on a satellite image by the value of the reflectance and irradiance can learn about the ecology of the cover of *Lemna obscura* seen in the image

METHODS

MODIS Images were selected from website by a period between 2001 – 2010. A medium resolution, from AQUA and TERRA satellites was found, with a spectral resolution from 0.40 µm to 14.38 µm. The software for viewing images and determination of spectral signature was the ENVI Version 4.3

For the selection of MODIS images, entered MODIS Rapid Fire Response System and then Realtime (http / / rapidfire.sci.gsfc.nasa.gov), looking for the exact time of passage of the respective satellite and then displaying the preview image, where the names of image files of interest. The data was downloaded from the Web page LAADS) Level 1 and Atmosphere Archive and Distribution System) of the Goddard Space Flight Center of NASA.

Raw image files displaying at the website offers a list of bands and reflectance radiance value. We follow a local radiance value to select a specific band. To setting up of this process will limit the area of interest to geo-reference, viewing of the western ward of Venezuela, using images of 500 m for a picture of 1200 pixels and 250 m for a picture of 2400 pixels. A few images combinations are displaying on screen conducting a series of bands with the purpose of distinguishing the *Lemna obscura*.

Once study area is created a vector of Maracaibo´s Lake which encompassed the study area, from ETM + image Lansat available in the Physical and Satellite Geodesy Laboratory and acquired the U.S. Geological Survey, using the ENVI program and subsequently exported to AutoCAD format to close it and use it as a vector in the processing software. The original vector ENVI format (extension. evf) was exported to a drawing file interchange format (extension. dxf) are editing in a software design.

Once having the georeferenced image (250 and 500m) and then the vector file was used to extract from each study area, eliminating unnecessary data and memory on the computer for digital classification, as follows.

Georeferenced image will be displayed, superimposing the vector area of interest.

Through the window bar menu options select the parameter vector and exports to regions of interest (ROI) by converting all the records in a single ROI polygon.

From the main menu bar choose the option Basic Tool / Subset data via ROIs, and select the input file, the region of interest associated with the image and the pixels are masked out of the vector, with a value for ND to 255

Each of these steps are performed for all images.

After that the spatial image is resembling, a procedure that allowed us to increase the spatial resolution of the study area. Several tests were performed with the procedures provided by the ENVI 4.3, such as IHS, Color Standard (Brovey), Gram-Schmidt Spectral Shapering, CP and CN Spectral Spectral Shapering.

File displayed is a mask creation consisting of a binary image with values of zero (0) and one (1). When used in a processing function, the areas with values of (1) are processed and those with values of zero (0) are excluded from the calculations. This is done in order not to take into account in the digital grading the area that is outside the study area.

The steps for creating the mask were the following: (López and Rodriguez, 2007)

It opened the vector of the study area on each image to process

The main menu was selected Basic Tools / Masking / Build Mask

Then imported the vector and was recorded in a file or loaded into memory the resulting mask.

This procedure is applied to all images.

After that in each image select Z profile spectrum and select areas to study in the images

FINDINGS AND DISCUSSIONS

The Maracaibo Lake covers an extensive area of water surrounded mostly by mountain, with one side open to the north. This particular topography makes the basin to have local phenomena whose intensity depends mainly on prevailing winds from the Caribbean.

Maracaibo Lake is located in a depression of Miocene origin, was once part of the vast sea that covered the central portion of Venezuela. At present, its area is 12,013 km^2, its maximum length, is 155 km. and 120 km width. The maximum depth in the southern portion of Lake is 34 meters. The Lake has a structure of two layers throughout the year. The lower layer or *hipolimnio* is shaped like a cone with its base in the bottom, in the central area of the lake at its apex variable one point near the center and about 5-10 meters in depth, so-called *hypolemnitic cone* (Parra-Pardi, 1979). The waters from *epilimnio* are moving in the opposite direction-clockwise. This movement of water bodies is consistent throughout the year, which could indicate that the Lake serves as a large-scale vortex Systems. This movement of water influences the distribution of various nutrients and some biological factors (Parra-Pardi, 1979).

Another aspect that should be mentioned is the role played by the *hypolemnitic cone* in nutrient recycling, maintaining a relatively high level of those components in the Lake. There is a large accumulation of decomposing organic matter and oxide-reduction processes in sediments of the cone. This raises a hypothesis, in which the vortex motion is accompanied by a secondary movement, much slower, the entry of surface water into the deepest parts, from near the banks of the lake toward the interface of the cone with a subsequent promotion to collide with it. The problem is that when the water entering the direction of the cone by the fund beats the interface; lose even more speed and causing sedimentation of the particles. This would explain the high content of organic matter in the sediments of the cone (Parra-Pardi, 1979).

The lake is in free communication with the marine waters of the Gulf of Venezuela through a 6 km channel. The channel and *El Tablazo* are collectively 39 km long. *El Tablazo* has three channels, two very shallow lying between the southern tip of the *Zapara* island and the *Barboza* island and between the *Barboza* island and the east coast of the *El Tablazo* bay, and other more profound, affecting on the west coast of *Zapara* island and the southern tip of the *San Carlos* island. The ship channel has been dredged through the channel.

The Gulf of Venezuela is at the outer portion of this depression. Its shape is roughly rectangular, with the major axis in the northeast – southeast direction. The outer limit of the Gulf to the waters of the Caribbean Sea on the north side is given by a line between *Punta Espada* and *Punta Macolla*.

The weather in the Maracaibo Lake is dominated by the regime of the trade winds that blow from the northeast regularly from November to April. During the warmer months, these winds change direction and are absent from the area from May to October. During this period dominated by local winds, causing a high incidence of rain, up to 90% of the total area. With the return of the trade winds stop the rain season. In this way, the climate of the region can be divided into two distinct phases, the rainy season from May to November and the dry season from December to April.

The system of winds in the Maracaibo basin can be divided into two distinct types (1) the trade winds that blow from the northeast only, November through April and (2) local winds that replaces the trade winds, adding to its

strength or canceling. These local winds are the uneven heating and cooling of the land masses surrounding the Lake Basin and Lake. During the day the earth absorbs more radiation and heats up faster. The layer of air adjacent to the land is heated and rises while the layer of air above the water remains cold and dense, resulting in a southwest wind. The wind begins to blow in the early morning hours, reaches its maximum velocity at noon and decreases towards the sunset; during the night and dawn, there is a reverse process that produces a northeast wind.

The rainfall increased in the basin from north to south. The Gulf of Venezuela presents the minimum values with 100 mm for the dry season and 200 mm. The averages are increasing towards the south, with two peaks, one on the Pit in River *Escalante*, with 1400 mm for the two stations and one on the Pit in River *Santa Ana*, with 1000 mm in the dry season and 1800 mm in the rainy season. The existence of this last area of high rainfall in the south is attributed to the existence of an area of low pressure near the *Catatumbo* river.

When the tidal wave from the Gulf enters the *El Tablazo* is considerably distorted by the extreme variations in the size of the bay, but not lost its fundamental characteristics. The tides in the Strait of Maracaibo and *El Tablazo* are semidiurnal mixed.

In the Lake there is a supply of fresh water from the runoff of rivers and rainfall on the Lake. This represents an annual discharge of about 49,000 million cubic meters of water that should come through the estuary to the Gulf. The bulk of the volume of runoff, up 57%, enters through the southwestern corner by the Catatumbo river. The position of the delta of the river makes its flow is discharged in direction perpendicular to the axis of the lake, creating a stream in southeast direction, parallel to the south shore of Lake. This stream is forced by the coast north to the height of *Cabimas*. At this altitude part of the surface water comes out the strait and the rest is diverted to the west.

Surface currents create a pattern of movement of the *epilimnio*, can achieve values of up to 1.8 km per hour. The measurements toward the center of the lake, in front of the mouth of the *Catatumbo* River indicate that the current direction does not change with depth, but the rate decreases from the surface to the bottom.

The manner in which cyclonic circulation in the lake water should be attributed mainly to the shape of the basin which forms the Lake, the system of winds which predominate in the northeast and the position of the mouths of major rivers in the south, mainly Catatumbo river.

The exchange of freshwater with seawater and the relationships between the various portions of the estuary are of primary importance in the distribution of plankton populations, eggs and larvae and contaminants entered or any material dissolved or suspended in the water. Such exchanges and the resulting distribution are listed on a regular basis in short periods of time with the oscillation of the tides and long periods with fluctuations in rainfall and the flow of rivers. In the case of ocean water, the concentration of each ion keeps a constant proportion with the concentration of chloride ion. The primitive origin of salts in the lake can not specify with certainty, however, the cause that has significance now is that the water of the lake has been salinized over time with sea water, by joint action of the cycles of tides, winds and currents that shows patterns of the estuary. It is very necessary to take into account as an action of significance, deepening and widening that has suffered the navigation channel of Maracaibo Lake in recent times, which has become a key factor in the increase of salinity (Bautista, 1997).

One occurs in the Lake of the presence of a salt wedge, which is caused by the exchange between seawater and freshwater in the Lake, from densities whose differences led to interface between the two bodies of water (stratified by density) and layer below the defined interface is known as saline wedge. All these factors involved in the mixture of this water to produce variations in the saline concentration.

The behavior resulting in the curve of time versus salinity leads to the conclusion that while it is true there is a seasonal pattern of salinity, governed by the rainfall, there is an increasing concentration of saline surface waters of the lake. Statistical analysis indicated the presence of a trend of increase in the average values of salinity in the *epilimio* observed for the seventies an average of 3057 mg/L, 3532 mg/L for the eighties and value of 4253 mg/L for the nineties.

In the Strait of Maracaibo the surface salinities fluctuate between 3.6 and 10.9 ‰, being higher in the east coast in the west, particularly during the month of March (Rodriguez, 2000). From December to March and in August

and September, salinity increase in April, May, October and November, decreases. These fluctuations, with two top-two minimum during the year, corresponding to the precipitation on the Lake. (Rodriguez, 2000).

The increased concentration in the salinity was due to start a process of deepening and widening of the navigation channel, which for the year 1938 had a depth of 11 feet and currently reaches 36 feet and connects on a more direct water of the Gulf to the waters of the lake. The increase in this time linked to the processes of reduction of runoff in the catchment input of fresh water lake that favors the entry of salt water to the Gulf and the internal process of seasonal *hipolinnetic* cone.

Basically, the lake has a relatively high level of nutrients on which overlap several areas of local production, downloads comparatively small but highly concentrated, high-impact locally. The problem of eutrophication is currently presented with features of an accelerated process in these areas that have been referred to as production areas and with a problem of eutrophication of different length and origin. (Marin, 2000).

One such area is a strip of 3 to 6 km in width off the north-eastern coast of Lake, between *Cabimas* and *Bachaquero*. This area is a significant number of domestic and industrial wastewater disposals, highly concentrated. Also here are the activities of the oil industry, which means pollution by oil residue and discharges of water formation. Today this area is exhibiting a more critical eutrophication process.

Rivas, in 2005, conducted a study on the influence of the concentration of oxygen in the release of nutrients, specifically orthophosphates (P-PO43-) and ammonium (NH4 +-N), since the sediments of Maracaibo Lake, found greater release under anaerobic conditions. In the case of Maracaibo Lake, some studies have shown that nitrogen is the limiting factor of production (Parra-Pardi, 1979). The main natural sources of nitrogen are: rain, organic and inorganic material of alien origin and molecular nitrogen fixation (N^2) within the system itself (Kelly, 1998).

It has been demonstrated in the case of Maracaibo Lake, through eco-simulation programs that in the process of decomposition of organic matter carried out by bacteria is a strong tendency to hypoxia and anoxia in the depths of Lake, This process is exacerbated by the stratification as a function of temperature and density in the water column, caused by the density of salt water entering the system from the Gulf and is deposited in layers below those of freshwater, this prevents stratification The hydrogen peroxide is mixed with water from the bottom of the lake.

Ecological conditions when *Lemna* appeared.

Some physical parameters in the Maracaibo Lake maintains invariable trough the years, but another shows some differences with the regular media, this changes are the result of the climatic variation and the contamination process that occurs in the ecosystem,

Evaluated images for the year 2001 show no change in the pattern of spectral signature in MODIS images. Observed by the factor of the pixel size of these images is not possible to answer some spectral differences which could show the water and clouds, both with the same spectral behavior observed in Figure 1, with high values for bands 1 (620-670 nm) and 3 (841-876 nm).
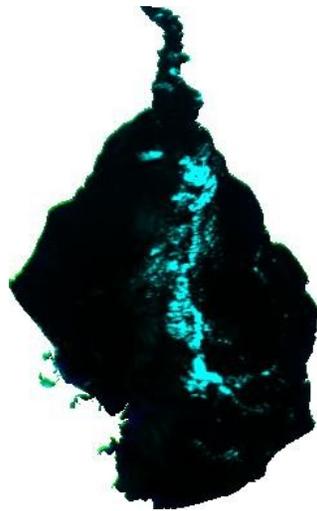
Figure 1. Maracaibo Lake Image, November, 2001.

For the year 2001 include images where there is not sort of algal bloom manifestation, the year corresponds with little rainfall in the basin and presumably little input of nutrients in the water body. Figure 2.
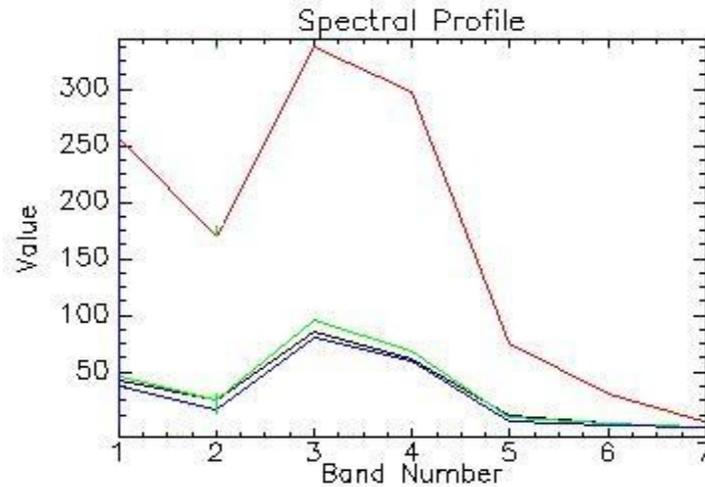

Figure 2. Spectral Signature of Maracaibo Lake, November 2001.

In December 2003 (Figure 3) are still getting the same spectral response of water only, water and clouds, but measurement at this year corresponds with the beginning of a period of heavy rainfall in the basin, with also observed some changes in certain hydrologic patterns.
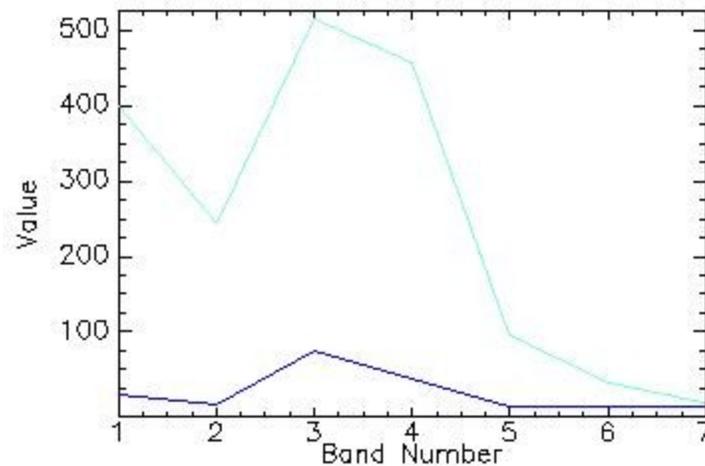
Figure 3. Spectral signature in November 2003

Basic climatic parameters:

Temperature: The upper layer of the lake maintained a media temperature about 31°C (3,5m), in the second layer (16m) the media is about 30°C, with a range of 1°C. In the year 2004 the media in the upper layer was 31.7°C and 29.6°C in the bottom layer, with a range between the two layers of 2°C. (Aldana et al, 2006)

Nutrients: Most of the values of the average analyzed for the wet year 2004 were higher compared with 1998, increasing at twice the concentration of nitrogen, however the ratio N/P = 1/26 in the *Catatumbo* River, N/P = 1/11 at the *Santa Ana* River and N/P = 1/0.76 in the *Chama* River, fell to roughly half its fraction. In the particular case of Santa Ana and the Chama Rivers phosphorus concentration increased from 4 to 5 times respectively.

This increase of phosphorus four times and twice the concentration of nitrogen were due to agricultural activities in the area and the leachate from the surface into the rivers during the wet period 2004.

The addition of nutrients to the lake through May 2004 for the wet period, resulting nitrate to a value of 0.30 mg/L (36%) and for the orthophosphate 0.055 mg/L (112%) in the *Catatumbo* river. *Santa Ana* River in the concentration of orthophosphate increment was 0.21 mg/L (320%) remained the largest increase in nutrient input. The maximum concentration of orthophosphate was recorded in the river Chama 0.34 mg/L (62%), however *Catatumbo* river do not showed the presence of *Lemna obscura* as the case of the *Santa Ana* River. (Aldana et al, 2006)

This alteration of the current value could give a hint on the reason of occurrence of the first stain of *Lemna obscura* in March 2004 compared to the mouth of the *Santa Ana* River, due to the significant increase of 320% concentration of orthophosphate in the river.

For this year 2004, we begin to notice at first glance presence of *Lemna obscura* in banks of Lake Maracaibo, also in MODIS satellite images, begin to notice with the highest proportion of emergence of a new spectral curve (figure 4), which coincides geographically with areas where they reported the appearance of *Lemna obscura*; observing these spectral curves can be noticed that their behavior resembles that of live vegetation.
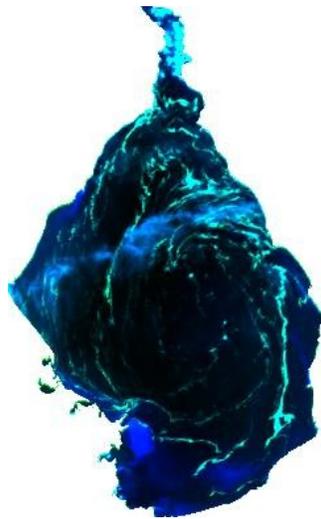
Figure 4. Maracaibo lake, May 2004.

The spectral signature of presumable *Lemna obscura* presents two pits in bands 2 (841-876) and 4 (545-565 nm), characteristic of vegetation (figure 5).
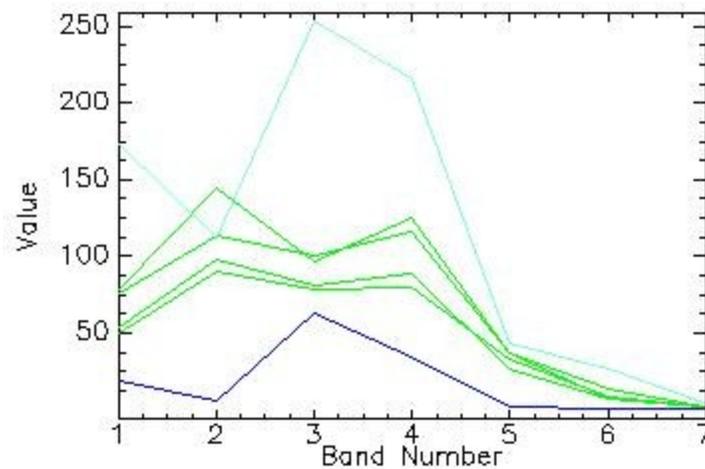

Figure 5. Spectral signature of water and *Lemna obscura* in Maracaibo Lake in May 2004.

Salinity: It is from the 90s until 2000 when it begins to observe significant changes in the concentration of salinity in the lake, probably associated with changes in temperature, *El Niño* phenomenon, warming of the globe, resulting in dilution the mass of water resulting in salinity concentrations of 2,600 mg/L closest to that obtained in 1937.

The lowest value recorded in the saline concentration in the lake after balancing period was 2,600 mg/L in 1989 and then after a decade again reach 2,700 mg/L (year 2000).

However the volume of dredged channel in the interior was reduced by 60% from 1998, reaching the lower value in the year 2004. These could be the reasons of the lower value of salinity.

This is how it is observed that the curves resemble *Lemna obscura* will decrease as measure approaches to the Strait, where there mayor salinity levels.

The role of water salinity in the *Lemna* growth.

According to studies conducted on tolerance to salinity of the water of the *Lemna* species present in the lake, it has been determined that it is played indifferently between salinities of 0 to 7,000 mg/L and may even reproduce, although to a lesser rate, to 10,000 mg/L. The average salinity of the lake is about 4,000 mg/L, which can be inferred that the salinity has not been a determining factor in the phenomenon of massive outcrop observed, but if they've helped. It is known that the lemnaceas vascular plants are fairly tolerant to salinity. The lesser values of salinity observed in the wet year of 2004 allows a better growth condition of *Lemna obscura* in the lake.

Nitrogen and Phosphorus as a limited nutrient in the *Lemna* growth.

The physical and natural conditions that exist to support the growth of *Lemna obscura* are associated with the temporary scheme of rain and winds that have defined the environmental conditions that favor the growth of this aquatic species. The most important are: the increase of rainfall that has determined the transport of nutrients from the rivers that feed the lake, particularly phosphates and nitrogen compounds in the form of nitrate from agricultural activities, industrial and urban develop in those basins, including the Colombian area of the *Catatumbo* River basin, covering an area of 16,000 km^2. The rains have also generated an increase in the flows of rivers that changed the hydrodynamics of the center of the body of the lake, causing the rupture of stratification existing in that area, which has led to the release of internal nutrients, especially nitrogen compounds, which provide the oxygen resulting from the breakdown of stratification, manage to transform itself from the forms of ammonium nitrate by a process of nitrification. The immediate availability of phosphates and nitrates from point sources (domestic wastewater discharges of industrial effluents and shrimp; and non-point pollution (runoff and atmospheric precipitation dry and wet), seems to favor the growth of *Lemna obscura* front other photosynthetic organisms present in the water as green algae and green-blue, the latter have been identified as the predominant species in the ecosystem. Another factor that has favored the occurrence and permanence of the outcrop of *Lemna obscura* is the predominance of low speeds winds (around 7 Km/h).

At high external loading rates, only part of the external phosphorus load to the water column can be taken up by the sediments, as the uptake capacity of the sediment is limited. This can lead to high concentrations of dissolved nutrients in the water column. Pleustophytic life forms (Den Hartong and Segal, 1964), that derive their N and P requirements solely from the water column are then in an advantageous position. Carbon dioxide is taken up directly from the atmosphere. (R. Porttielje, R.M.M. Roijackers 1995). *Lemna obscura* derives its P requirements solely from the water column. The dominance by *Lemna obscura* can only take place after the dissolved phosphorous concentrations in the water column have increased. These concentrations can only increase after the system has lost its ability to keep them low, either through storage in the sediments from the water column is limited by a maximum, and so is the uptake rate of phosphorus by the vegetation, owing to maxima in both plant biomass and internal P concentration. The overall uptake rate was slightly lower than the external loading rate in the highest loaded ditch. This resulted in increasing nutrient concentrations in the water columns. This is probably a precondition for the occurrence of pleustophytic life forms. At lower external nutrient loading rates, however, a decrease of the sedimentary P pool was observed. In this case the sediments released P, which sustained the growth of macrophytes. (R. Porttielje, R.M.M. Roijackers(1995)

Succession between *Lemna* and other aquatic plants and Phytoplankton.

In water bodies it is assumed that the quantity and variety of phytoplankton and macrophytes are related with the quantities of nutrients, but also could be related with the water quality (for example salt content and the case of Maracaibo Lake where the salt concentration give the areas where certain macrophytes and algae could develop). (Barboza et al, 2008).

"In lakes eutrophication usually causes a decline of submersed aquatic macrophytes caused by excessive growth of periphytic and filamentous algae. This then gives way to phytoplankton blooms (Phillips et al, 1978), which are generally considered to cause most of the nuisance related to cultural eutrophication (Van Straten, 1986). Competition with species with floating or emerged leaves may also cause the disappearance of submersed species, especially in small water bodies. This results in a decline of the ecosystem diversity, as

concomitantly the secondary producers that depend on submersed macrophytes for various purposes disappear. (R. Porttielje, R.M.M. Roijackers,1995)

At low nutrient concentrations in the water column, the water is clear so that light can sufficiently penetrate to the bottom zone, where the production zone is located. In shallow waters, rooted macrophytes derive their nutrient requirement from the sediment (Barko and Smart, 1980) In stagnant waters, where a root system is not necessary for anchoring, the function of the roots is mainly restricted to nutrient uptake" (R. Porttielje, R.M.M. Roijackers 1995)

At intermediate trophic states, with varying concentrations of dissolved nutrients in the water column, uptake from the sediments and the water column can occur alternately. Aquatic macrophytes can be capable of significant nutrient uptake from the water column (Phillips et al 1978). This can be either foliar uptake or uptake by a part of the root system that is suspended in the water (Agami and Waisel, 1986). This necessity for an energically unfavorable underground root system decreases with increasing trophic state of the water column. The survival of an autrotrophic species then mainly depends on its ability to compete for light, carbon and the available space. This results in a movement of the production zone even above the water surface. Submersed species in ditches then switch from a vertical to a horizontal growth pattern. For them, optimal occupation of the zone just below the water surface is of competitive advantage, both with respect to light interception and the availability of atmospheric carbon: enhanced primary production induces a higher pH, which in turn enhances the CO_2 flux from the atmosphere (Portielje and Lijklema, 1995). The atmospheric C-flux can be high enough to sustain a considerable net primary production during the growth season. (R. Porttielje, R.M.M. Roijackers(1995)

Under suitable conditions *Lemna* can continuously develop, covering large water areas, unless the available water surface is limited. Indeed, on saturated water surfaces, the aquatic equilibrium is markedly modified since no light rays can pass through the dense plant mat. The growth of any given species is known to be government by the size of its population; however, the specific effect of plan mat density has been scarcely studied. (Monette Frederic et al, 2006). In the case of the Maracaibo Lake, which a great quantity of N and P in the water column the *Lemna obscura* find environmental conditions to develop and dominated the ecosystem.

Thus it appears that the occurrence of *Lemna obscura* was relatively constant during the years 2004 to 2007, images taken for the year 2007 (figure 6) also show a large presence of *Lemna obscura* and the same behavior of the spectral signatures evaluated these conditions were favored the high rainfall that occurred during those years
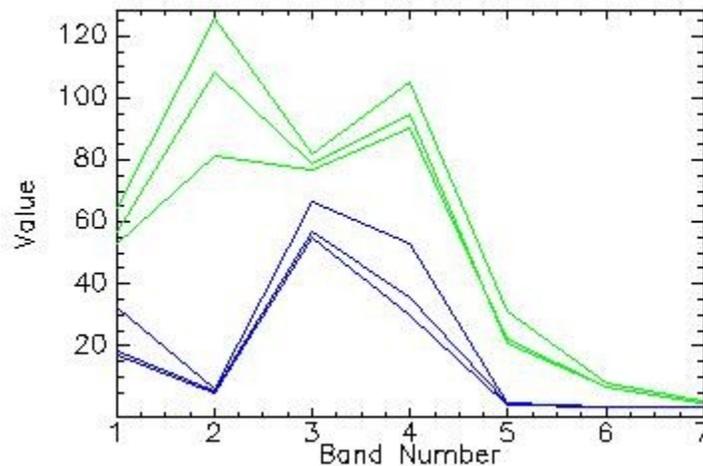

Figure 7. Espectral signature for water and *Lemna obscura*

Since the year 2010 is beginning to notice a decrease in rainfall and river flow tax, this presumably influenced the reduced supply of nutrients to the lake, did not epilimic mixed cone and therefore the conditions were not

suitable for the growth of Lemna in that year, which was observable in satellite images which did not present the characteristic of presumably *Lemna obscura*. (Figure 8).
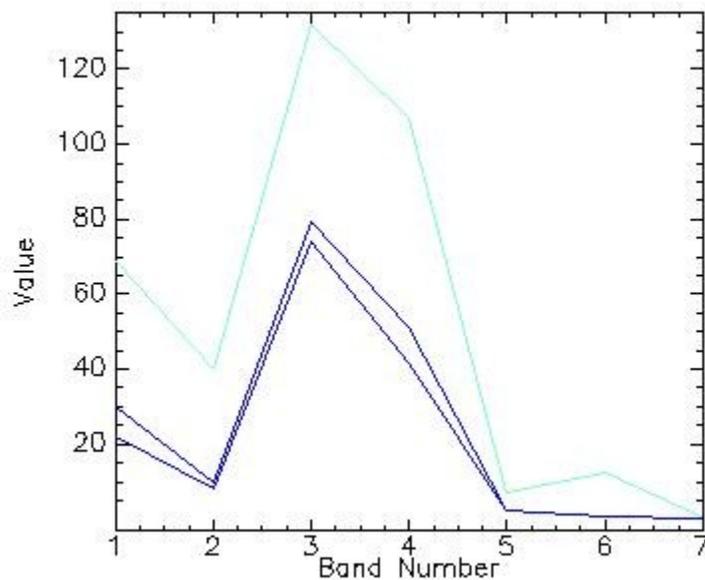

Figure 8. Spectral signature of water year 2010.

Conclusions.

The appearance of *Lemna obscura* in the Maracaibo lake is a new evidence of the cultural eutrophication process that has been develop in the Maracaibo basin since the beginning of the 21th Century, the condition which determinate the appearance of this new specie in the lake was the big quantity of rainfall who allows the decreases of the salinity level in the Maracaibo Lake and the transport of more nutrient into the Lake necessary for the develop of the macrophytes. Is expect that in the case that the big quantity of fresh water input continues into the Lake another aquatic species adapted to a fresh water environment could colonized the area instead the *Lemna obscura.* The develop of this macrophyte could be well evaluated using the spectral signature and GIS technologies

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