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Simulation of spectral bands of the MERIS sensor to estimate chlorophyll-a concentrations in a reservoir of the semi-arid region[1]

Simulação de bandas espectrais do sensor MERIS para estimativas das concentrações de clorofila-a em reservatório da região semiárida

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Abstract: Nowadays, the monitoring of water is essential for the sustainability and better management of water resources. The use of remote sensing data is important, since it allows evaluation of dynamic problems in aquatic systems, such as the eutrophication of bodies of water and suspended sediment. The aim of this study was to estimate chlorophyll-a concentrations in a reservoir of the semi-arid region of Brazil using simulated orbital-sensor data, as an aid in the management of water resources. The study area corresponded to the Orós reservoir, in the State of Ceará, Brazil. Water samples for analysis of the chlorophyll-a and measurements of the spectral radiance of the aquatic system were collected from 20 points. The radiance was measured by spectroradiometer. The data were collected in June and August of 2011. The model using three bands of the MERIS sensor (7, 9 and 10) presented an R^2 of 0.84. For the two-band model (7 and 9), the value of R^2 was 0.85. The waters of the Orós reservoir were all classified as eutrophic. The main optically active component in modelling the shape of the spectra was chlorophyll-a. The models showed a mean absolute error (MAE) of 3.45 and 3.61 µg L^{-1} for the three- and two-band models respectively. The models displayed high coefficients of determination, i.e. the simulations show the feasibility of estimating chlorophyll-a concentration from the data of the MERIS orbital sensor.

Key words: Continental water. Monitoring. Remote sensing.

Resumo: O monitoramento da água nos dias atuais é essencial para a sustentabilidade e para a melhor gestão dos recursos hídricos. O uso de dados de sensoriamento remoto é relevante, uma vez que permite a avaliação de problemas dinâmicos em sistemas aquáticos, tais como a eutrofização de corpos de água e dos sedimentos em suspensão. Objetivou-se estimar as concentrações de clorofila-a em reservatório da região semiárida do Brasil, usando dados simulados de sensor orbital, como suporte à gestão dos recursos hídricos. A área de estudo corresponde ao açude Orós, no estado do Ceará. As amostras de água para análise da clorofila-a e as medições da radiância espectral do sistema aquático foram coletadas em 20 pontos. As medidas de radiância foram realizadas utilizando um espectrorradiômetro. Os dados foram coletados nos meses de junho e agosto de 2011. O modelo usando três bandas (7, 9 e 10) do sensor MERIS apresentou R^2 igual a 0,84. Para o modelo de duas bandas (7 e 9), o valor de R^2 foi de 0,85. As águas do reservatório Orós foram todas classificadas como eutróficas. O principal componente opticamente ativo modelando a forma dos espectros foi clorofila-a. Os modelos apresentaram um erro médio absoluto (EMA) de 3,45 e 3,61 µg L^{-1}, respectivamente, para os modelos de três e de duas bandas. Os modelos apresentaram coeficientes de determinação altos, ou seja, as simulações mostram a viabilidade de se estimar as concentrações de clorofila-a a partir dos dados do sensor orbital MERIS.

Palavras-chave: Águas continentais. Monitoramento. Sensoriamento remoto.

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INTRODUCTION

Water is the most important substance in nature because the existence of all known life forms depends on it. According to UNESCO (2012), it is estimated that the world's urban population will increase from 3.4 to 6.3 billion people in the period from 2009 to 2050. With the growth in the demand for water and the increase in pollution, the availability of fresh water and the likelihood of supply is reduced. To make matters worse, in recent decades, water quality has been deteriorating rapidly, which has prevented the use of important reservoirs as a means of controlling the shortage. Maintaining the supply of water, not only in quantity but also quality, will therefore become one of the major challenges to be overcome by society.

In both arid and semi-arid regions at low latitudes, dams and the artificial year-round use of rivers make up the main source of water for domestic, industrial and agricultural consumption, making the prevention and control of pollution of these water sources indispensable. It is a fact that to assess the status of the quality of surface water, it is necessary to implement programs for monitoring the physical, chemical and biological factors involved (BOUZA-DEAÑO *et al*., 2008; LOPES *et al*., 2014a; ROCHA *et al*., 2015).

Eutrophication is a major problem for water management and refers to the process by which aquatic environments suffer enrichment with nutrients, mainly phosphorus and nitrogen which are essential for the growth of phytoplankton (microalgae and cyanobacteria) and macrophytes (aquatic plants).

In the Northeast, and in the state of Ceará, the risk of eutrophication of lentic aquatic systems is greater due to the high levels of insolation, high rates of evaporation, long water residence time (COSTA *et al.*, 2009), low levels of sewage treatment, lack of riparian vegetation, and illegal use and occupation, which all accelerate the eutrophication process (LOPES *et al.*, 2014a; Santos *et al.*, 2014) and the consequent growth of microalgae and cyanobacteria (COSTA *et al.,* 2009).

Nowadays, monitoring the water is essential for the sustainability and better management of water resources. The use of remote sensing data can make monitoring more successful, and shows the great potential of monitoring on different spatial and temporal scales (LOPES *et al.*, 2014b).

The use of remote sensing data is important, since it allows the evaluation of dynamic problems in aquatic systems, such as the eutrophication of bodies of water and of suspended sediment (LOPES *et al.*, 2014b).

Photosynthetic pigments, suspended sediment, dissolved organic matter and water molecules are themselves the main agents which govern the optical properties inherent in water (MOBLEY, 2004), and are therefore known as optically active components (OACs). The spectral effects of OACs on water reflectance have been widely discussed in the literature (NOVO *et al.*, 2004; LE *et al.*, 2013; MOSES *et al.*, 2012; LOPES *et al.*, 2014b). In this regard, several studies and methods using remote sensing have been proposed and developed with a view to obtaining quantitative spatial measurements of such variables as chlorophyll-a and inorganic suspended solids, among others (DALL'OLMO; GITELSON, 2005; NOVO *et al.,* 2013; CARVALHO *et al.*, 2014; BARBOSA *et al.*, 2015).

In this context, the use of remote sensing becomes an important tool for monitoring aquatic systems and their watersheds, as it provides a synoptic view of the environment, allowing the identification of critical areas of pollution in the watershed and of nutrient input to surface reservoirs. The aim therefore was to simulate the spectral responses of the bands of the MERIS orbital sensor and evaluate the performance of models used to estimate the chlorophyll-a concentration in a reservoir of the semi-arid region of Brazil using the simulated data.

MATERIAL AND METHODS

The area under study corresponds to the Orós reservoir, the main reservoir of the Upper Jaguaribe watershed, in the south central area of the State of Ceará (Figura 1). The dam of the reservoir was completed in 1961 by the National Department for Works to Counter Drought - DNOCS, for the purpose of allowing year-round use of the Jaguaribe river, with a view to supplying the population (of the regions around Jaguaribe and metropolitan Fortaleza, the capital of Ceará), and to developing irrigated agriculture, fish farming and tourism. The Orós reservoir (Figure 1) has a storage capacity with a bleed rate of 1.9 billion m^3 of water and a surface area of approximately 190 km^2.

According to the Köppen classification, the region presents a type BSw'h' hot semiarid climate with maximum rainfall in the autumn and average monthly temperatures consistently above 18ºC. The average annual rainfall (1974 to 2011) is 998 ± 321mm, concentrated from January to May; evaporation measured by Class A Tank is around 1,988 mm yr^{-1}; the relative humidity is 66.1%, with winds at a speed of 1.8 m s^{-1} and an insolation of 2,945 h $year^{-1}$.

Water samples were collected at a depth of 30 cm from the surface, packed into Styrofoam containers with ice, and sent to the laboratory for analysis of the chlorophyll-a. The data was collected from 20 points (Figure 1) during June and August of 2011.

At the same time as the water samples were collected, measurements were taken of the spectral radiance of the water system using an ASD FieldSpec®3 Hi-Res spectroradiometer (Figure 2) that covered the 350-2500 nm spectral range, with a field of vision of 25° and spectral resolution of 1.4 nm. A Spectralon reference plate was also used to represent a Lambertian surface. Measurements were

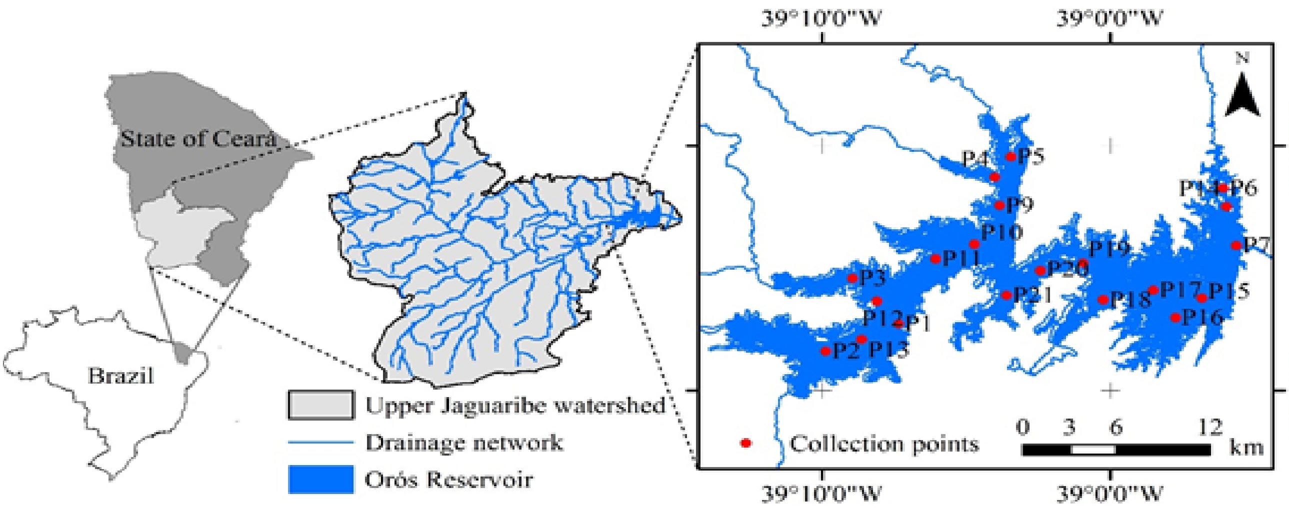

Figure 1 - Location of the Orós reservoir and collection points.

Figure 2 - Procedures for collecting radiometric data in the Orós reservoir, Ceará: (A) Reading of the Lambertian Panel, (B) Close-up of the reading of the panel, (C) Reading of the spectral radiance of the aquatic system, (D) Close-up of the reading of the spectral radiance of the aquatic system.

taken between 10:00 and 14:00, at the time of the smallest angle of solar inclination, the greatest flow of radiant energy, under suitable weather conditions, with little wind and the sky mostly free of clouds.

Radiometric measurements were taken following the procedures of a methodology proposed by Milton (1987), i.e. preserving to the maximum equal conditions of lighting and surface water. To minimise specular reflectance from the water, the spectroradiometer was positioned at each sampling point with a sight axis of 40° inclination to the vertical and 90º azimuth relative to the position of the Sun. The height of the sensor in relation to the water surface was 1 m, with an approximate size for the area to be imaged of 0.7 m^2 (Figure 2).

Ten measurements of water radiance were carried out for each point, so that measurements which were unrepresentative could be discarded, and a mean value calculated for the remainder. The values for spectral radiance were converted into a bidirectional reflectance factor with the expression:

$$FRB_{\lambda} = L_{a,\lambda} / L_{r,\lambda} \qquad (1)$$

where: FRB_{λ} = Bidirectional reflectance factor (dimensionless); $L_{a,\lambda}$ = Target spectral radiance (W/cm².sr.µm); $L_{r,\lambda}$ = Reference panel spectral radiance (W/cm².sr.µm).

To verify the effectiveness of estimating the optically active constituents in bodies of water using orbital sensing images, the width and number of spectral bands of the MERIS (Medium Resolution Imaging Spectrometer) orbital sensor were simulated from spectral curves obtained by field radiometer. The 15 bands of the MERIS sensor cover the main features that allow the detection of chlorophyll-a (400 to 900 nm). The spatial resolution (300 m) is compatible with the dimensions of a large water storage reservoir, and the sensor was in operation for around ten years (2002-2012), making it useful in monitoring the impact that changes in land use and occupation have on water quality.

The simulation of one spectral band from other spectral bands is only possible if there is substantial spectral overlap between the band to be simulated and the bands used to perform the simulation (MASCARENHAS *et al.*, 1991). The method uses the spectral curves of the sensors as input, and the procedure basically consists in the weighted sum of these curves, where the weightings define the contribution of each band.

Generally speaking, the broad band (i) of the orbital sensor is considered as being made up of n narrow bands of the ASD FieldSpec®3 Hi-Res spectroradiometer, which range from x to y, where x and y are the bands of the first and last channels that respectively contribute to the band (i) of the orbital sensor.

The radiance of the simulated band (L(i)) is formed by the sum of the product of the weighted spectral response function (WSRF(c)) and the radiance of the spectroradiometer (L(c)) for each channel making up the band. Therefore:

$$L_{(i)} = \sum_{x}^{y} \mathrm{WSRF}_{(c)} * L_{(c)} \qquad (2)$$

To calculate the regression models, data from August 2011 were used (as they showed the highest concentrations of chlorophyll-a), and then validated using data from June 2011, avoiding any effect from autocorrelation of the data, which could give biased results.

To evaluate statistically the performance of the models and errors in the estimates, statistical indicators were calculated by comparing the estimated values with measurements not used in the regression analysis. The following statistical indicators were used in the evaluation: correlation coefficient (r); coefficient of determination (R^2); F-test; Willmott's index (d); Nash-Sutcliffe efficiency coefficient (NSE); mean absolute error (MAE) and root mean square error (RMSE).

The Pearson correlation coefficient is a measure of the degree of linear relationship between two quantitative variables. The value of this coefficient varies between -1 and 1. A value of 0 (zero) means that there is no linear relationship, a value of 1 indicates a perfect linear relationship, a value of -1 also indicates a perfect linear relationship, but inverse, i.e. as one of the variables increases the other decreases. The closer this value is to 1 or -1, the stronger the linear association between the two variables (Table 1).

The precision is given by the correlation coefficient, which indicates the degree of dispersion of the data in relation to the mean, that is, the random error. The coefficient of determination, R^2, is the percentage variation in the dependent variable explained by the independent variable(s) (Table 1).

Table 1 - Interpretation of Pearson's correlation coefficient and coefficient of determination

Pearson Scale		
Weak	Moderate	Strong
$0 \leq r \leq 0.50$	$0.50 \leq r \leq 0.90$	$0,90 \leq r \leq 1.00$
$0 \leq r^2 \leq 0.25$	$0.25 \leq r^2 \leq 0.81$	$0.81 \leq r^2 \leq 1.00$

Source: Adapted from Milton (1992).

Willmott's index (d) was calculated from Equation 3 (WILLMOTT *et al.*, 1985), where values range from zero, for no agreement, to 1 for perfect agreement. Values of d greater than 0.75 are considered satisfactory.

$$d = 1 - \frac{\sum (Pi - OI)^2}{\sum (|Pi - O| + |Oi - O|)^2} \qquad (3)$$

where: d - is Willmott's index of agreement; Pi - expresses the estimated value of the variable; Oi - represents the observed value; O - defines the mean of the observed values.

The coefficient defined by Nash and Sutcliffe (1970) reflects similarity in the variability of two variables; it indicates similarity of quantification, considered important in evaluating reliability and efficiency in models, and is an important statistical criterion for assessing their precision. It was determined with equation 4:

$$NSE = 1 - \left[\frac{\sum (Y_m - Y_c)^2}{\sum (Y_m - \overline{Y}_m)^2}\right] \quad (4)$$

where: NSE – Nash-Sutcliffe coefficient, ($-\infty < NSE \leq 1$); Ym – measured value; Yc – calculated value; $\overline{Y}$ - mean of the measured values.

This coefficient varies from $-\infty$ to 1, with 1 being a perfect fit. The performance of a model is considered as adequate or good if the value of NSE exceeds 0.75, and is considered acceptable when this value is between 0.36 and 0.75. When the NSE coefficient presents values of less than zero, this indicates that the mean value for the data series under study will be a better indicator than an estimate using the model.

The mean absolute error (MAE) is defined as the sum of the magnitudes of the differences between prediction and observation, divided by the number of observations (Equation 5):

$$EMA = \frac{1}{N}\sum_{i=1}^{N}\left|X'_i - X_i\right| \quad (5)$$

where: X_i are the measured data; X_i' are the estimated data and N is the number of pairs of points used. Where a prediction is perfect, the MAE will be zero.

The root mean square error (RMSE) was obtained with Equation 6. This method indicates the degree of similarity between the measured data and the data estimated using the models, the ideal value being equal to zero. The RMSE is more sensitive to extreme values.

$$REMQ = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[X'_i - X_i\right]^2} \quad (6)$$

RESULTS AND DISCUSSION

A descriptive analysis and spatial variability of the limnological attributes used in this study are shown in Table 2. It can be seen that the hydrogen-ion potential - pH had a

Table 2 - Spatial variability of the limnological attributes, August 2011

Point	pH	CE	Cl-a	Turbidity	Transparency
	-	(dS m^{-1})	(μg L^{-1})	(NTU)	(m)
P3	7.57	0.23	28.25	5.10	0.69
P4	7.62	0.20	41.28	4.70	0.55
P5	7.48	0.23	46.99	5.50	0.64
P6	7.52	0.25	18.80	4.40	1.40
P7	7.63	0.25	14.58	3.90	1.46
P9	7.85	0.23	34.71	3.90	0.68
P10	7.61	0.24	25.42	4.40	0.85
P11	7.59	0.23	27.23	4.20	0.83
P12	7.71	0.23	32.79	4.30	0.78
P13	7.73	0.23	25.31	6.00	1.40
P14	7.81	0.25	15.59	4.10	1.62
P15	7.67	0.23	18.85	3.50	1.65
P16	7.66	0.23	19.25	2.60	1.25
P17	7.75	0.23	19.65	4.40	1.25
P18	7.58	0.23	22.91	3.60	1.09
P19	7.74	0.24	12.02	4.40	1.09
P21	7.70	0.23	25.79	3.80	0.85
Mean	7.66	0.23	25.26	4.28	1.06
Standard Deviation	0.10	0.01	9.16	0.76	0.35
Minimum	7.48	0.20	12.02	2.60	0.55
Maximum	7.85	0.25	46.99	6.00	1.65

minimum value of 7.48, a mean value of 7.66 and a maximum value of 7.85, i.e. there was little variability. These results are corroborated by the studies of Ferreira *et al.* (2015) and Rocha *et al.* (2015) for the same reservoir. The pH is a complex attribute to interpret due to the large number of factors that can influence it (Lopes *et al.*, 2008). According to CONAMA Resolution No. 357/2005, standard values for Freshwater Class II should be between 6.0 and 9.0 (BRAZIL, 2005).

It was found that the electrical conductivity of the water - EC had a minimum value of 0.20, a mean of 0.23 and a maximum of 0.25 dS m^{-1}. Similar results were found by Sales *et al.* (2014) when studying water quality in the Orós reservoir for the purposes of irrigation. Analysing the EC for use in irrigated agriculture, they note that the waters of the Orós reservoir present no risk of causing problems of soil salinisation, EC < 0.70 dS m^{-1} (AYERS; WESTCOT, 1999). The waters of the Orós reservoir can be used for all types of soil and crops.

In the process of eutrophication, chlorophyll-a concentrations are considered a measure of the response of the body of water to the presence of nutrients, mainly of total phosphorus and total nitrogen, being an indicator of algal biomass (WETZEL, 2001). Thus, the presence of nutrients and chlorophyll can be seen as satisfactory indicators of the cause and effect of eutrophication.

At every point sampled, the chlorophyll-a concentration was over the 12 μg L^{-1} limit set by Salas and Martino (2001) to classify a body of water as eutrophic. The level of eutrophication of the samples is indicative of the occupation, use and inadequate management of the soil around the reservoir, watershed and basin (LOPES *et al.*, 2014a; SANTOS *et al.*, 2014.). The production of chlorophyll-a is influenced by several factors, such as the inflow of nutrients, mainly total phosphorus and nitrogen, temperature and water transparency (AZEVEDO *et al.*, 2008; BATISTA *et al.*, 2014).

It can be seen that the respective minimum, mean and maximum values for turbidity were 2.60, 4.56 and 6.00 NTU (Table 2). According to CONAMA Resolution No. 357/2005, the values for turbidity were below the limit for Freshwater Class I, which is up to 40 NTU (BRAZIL, 2005). The main cause of the increase in turbidity of the water are suspended solids, which can be of natural origin (rock particles, sand and silt, as well as algae and other minerals), or anthropogenic (household and industrial discharge, microorganisms and eroded sediment). Human activity, a lack of sanitation, agriculture, solid waste, industry and many other activities pose risks to water quality (BRAZIL, 2005).

Turbidity decreases the penetration of energy incident on the surface of the water, reducing photosynthesis, which in turn reduces replenishment of the oxygen (FARIAS, 2006). Inorganic particles cause the silting of reservoirs and dams, consequently reducing the water storage capacity. Araújo (2003), studying siltation in seven reservoirs of the semi-arid region, concluded that the mean volumetric rate of decay is 1.85% every decade; a reduction which is due to sediment input.

The values for water transparency for the period (Table 2) ranged from 0.55 to 1.65 m for points P5 and P15 respectively. A strong spatial variation was found between sampling sites for water transparency. The lowest values for transparency were seen for the points located in the upper part of the watershed, corresponding to the shallowest part of the reservoir and also to the main entries to the reservoir (Figure 1). Only points P6, P7, P13, P14 and P15 were classified as mesotrophic, i.e. with values for transparency greater and/or equal to 1.1 m, and less than 1.7 m; the remaining points were classified as eutrophic, with transparency values of less than 1.1 m (TOLEDO *et al.*, 1984).

The spectra of the bidirectional reflectance factor related to the campaign carried out in August of 2011 in the Orós reservoir is shown in Figure 3A. In Figure 3B can be seen the results of the simulation of the spectral bands from the MERIS orbital sensor (multispectral). The spectral response of a body of water is shaped by the composition and concentration of the optically active components present. The spatial dynamics of the composition and concentration of the limnological attributes of the water of the Orós reservoir (Table 2) influenced the shape and amplitude of the spectra (Figure 3).

Features characteristic of the spectral response of water rich in chlorophyll-a can be seen for all sampling points (Figure 3A). There is low reflectance, of between 400 and 500 nm, due to absorption by pigments and by organic substances dissolved in the water of the region (MANTOVANI, 1993; MOBLY, 2004). There is also a dip at 438 nm (Figure 3A) due to absorption by chlorophyll-a. Maximum reflectance, in the green region, around 550 nm, is due to less absorption by the pigments. Whereas minimum reflectance, in the red region, around 668 nm, is due to absorption by chlorophyll-a. In the region around 700 nm there was a peak in reflectance, attributed to high levels of scattering and minimum absorption for all the optically active components, including the pure water (GITELSON, 1992; DALL'OLMO; GITELSON, 2005; LE *et al.*, 2013).

The simulated bands from the MERIS sensor were able to capture the characteristic features of the spectral behaviour of water where the optically active constituent present in the water system is chlorophyll-a (Figure 3B). Particularly notable were the low reflectance in bands 1 (412.5 nm) and 2 (442.5), due to absorption by chlorophyll-a, and a maximum of reflectance in the green region, band 5 (560 nm), due to the low absorption by the pigments. Bands 7 (665nm) and 8 (681.3 nm) showed a minimum of reflectance in the red region, a result of the absorption by chlorophyll-a, a peak in reflectance in band 9 (708.8 nm), attributed to high scattering and minimum absorption by the optically active components, and low reflectance for the bands located in the near infrared region.

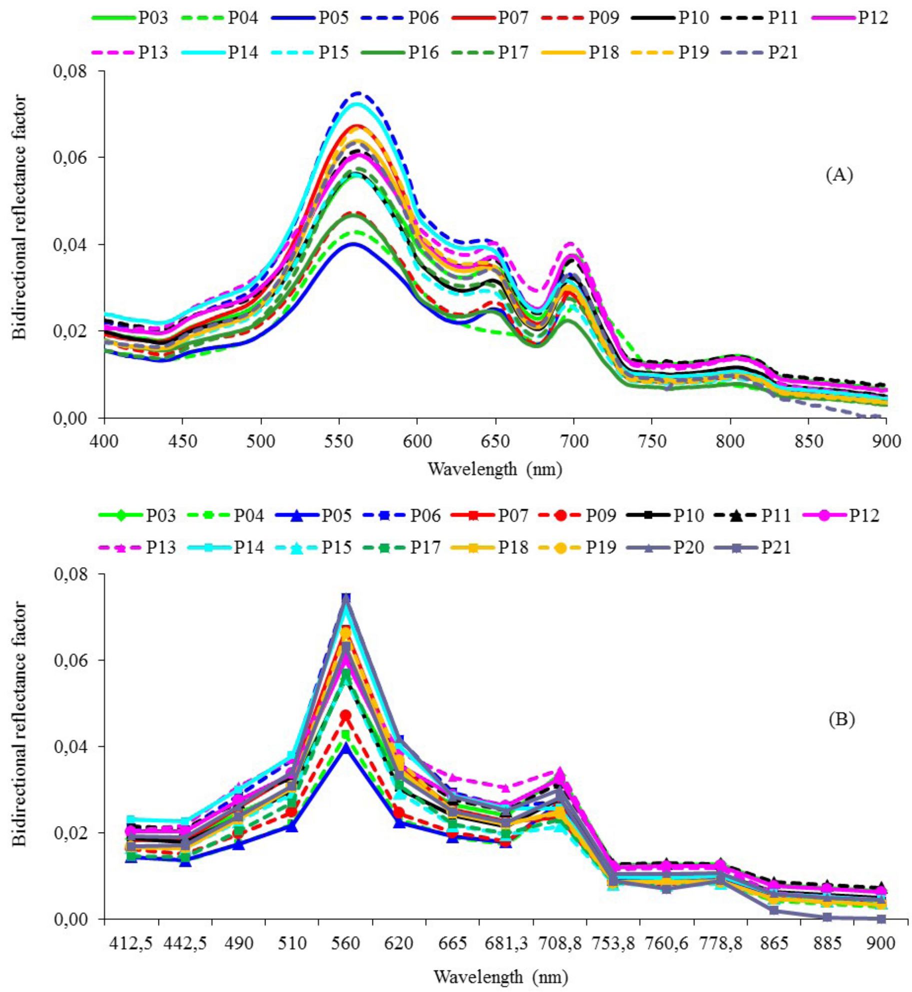

Figure 3 - In-situ spectral response of the Orós reservoir aquatic system, Aµgust 2011 (A) Simulation of spectral bands of the MERIS sensor from in-situ reflectance data, August 2011 (B)

The results of the models determined for estimation of chlorophyll-a concentrations for the Orós reservoir in the State of Ceará, using simulated data from the MERIS sensor, are shown in Figure 4. The model employing three bands (7, 9 and 10) of the MERIS sensor (Figure 4A) displayed an R^2 of 0.84. For the two-band model (7 and 9), the value for R^2 was 0.85 (Figure 4B). Both models had high coefficients of determination, i.e. the simulations demonstrate the feasibility of estimating concentrations of chlorophyll-a using data from the MERIS orbital sensor. The models show that, as they were significant ($p < 2.7 \times 10^{-7}$), chlorophyll-a concentrations can be estimated using data from the MERIS orbital sensor.

To assess whether the errors in estimation followed a trend, the residuals of the models were observed in scatter plots for the chlorophyll-a concentration data collected *in situ*. No clear pattern was found of a systematic increase in the residuals with increases or reductions in chlorophyll-a concentrations, that is, the errors are distributed randomly (Figure 5).

It further appears that the residuals are randomly distributed around zero, and that all the residual errors fall between -2 and 2 (Figure 5). Lopes *et al.* (2014b) found similar results with models developed for the attributes of inorganic suspended solids, turbidity and transparency for the Orós reservoir, Ceará.

The models, adjusted for the simulated MERIS sensor data, show a correlation coefficient (r) of 0.89 and 0.88, a Willmott index (d) of 0.94 and 0.93, and a Nash-Sutcliffe coefficient (NSE) of 0.77 and 0.77 for the three- and two-band models respectively. The models also displayed a mean absolute error (MAE) of 3.45 and 3.61 $\mu g\ L^{-1}$ respectively for the three- and two-band models. The root mean square error (RMSE) for the models were 4.26 $\mu g\ L^{-1}$ for the three-band model and 4.35 $\mu g\ L^{-1}$ for the two-band model (Figure 6).

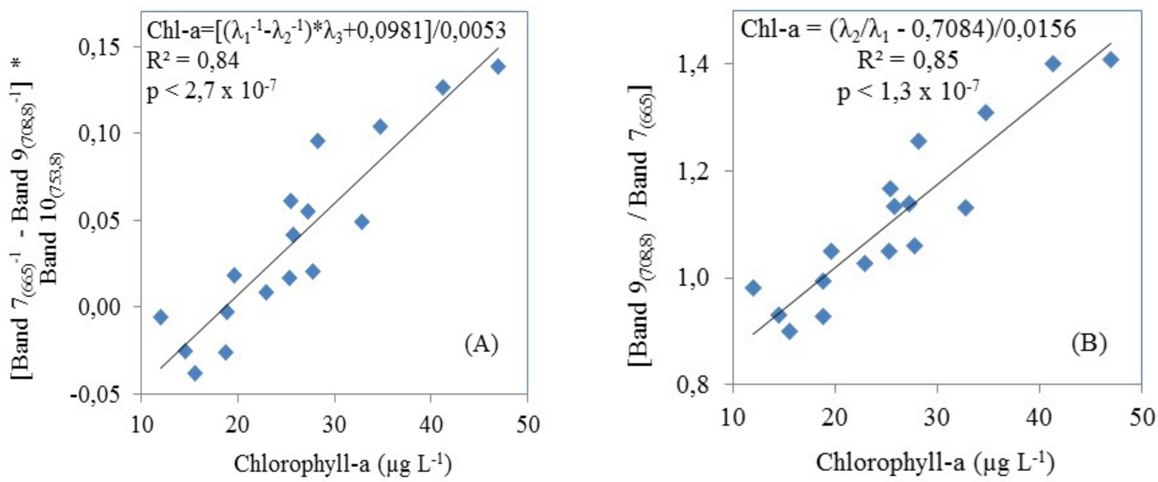

Figure 4 - Models for estimating chlorophyll-a concentrations for the Orós reservoir, using simulated bands from the MERIS sensor, (A) three bands and (B) two bands

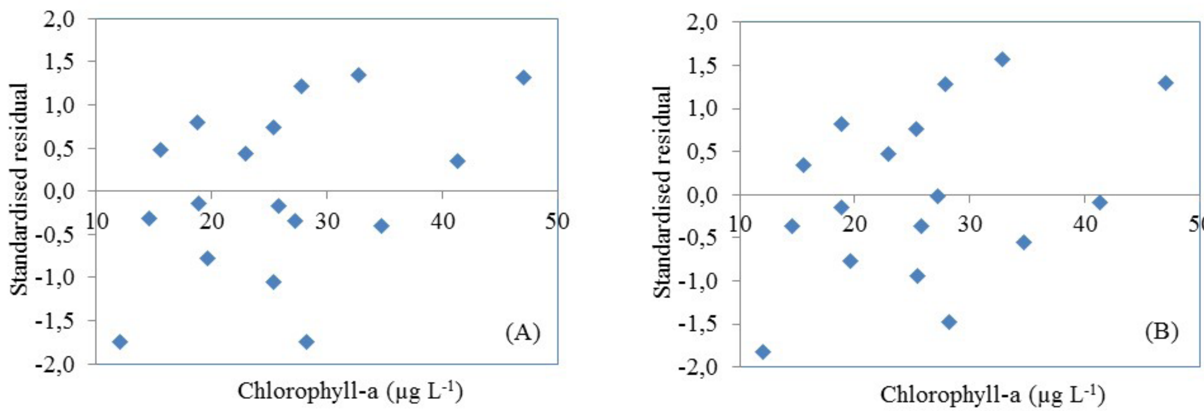

Figure 5 - Dispersion between the residuals and chlorophyll-a concentrations for the Orós reservoir, for simulated bands from the MERIS sensor, (A) three bands and (B) two bands

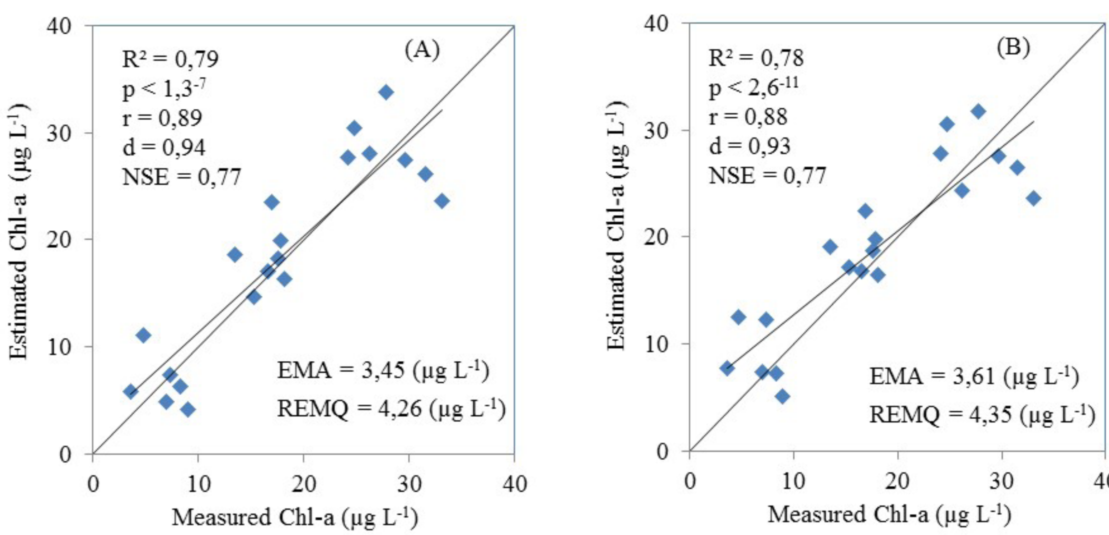

Figure 6 - Validation of the models for the quantification of chlorophyll-a, using chlorophyll-a concentrations and simulated data from the MERIS sensor, June 2011: (A) three bands and (B) two bands

It can be seen that for both models the relationship between the measured and estimated data was statistically significant at 1%. The models proved to be quite reliable, demonstrating that concentrations of this attribute can be estimated from remote sensing data from the MERIS orbital sensor with a high degree of reliability. Both models can be used to quantify remotely chlorophyll-a concentrations in reservoirs of the semi-arid region.

CONCLUSIONS

The waters of the Orós reservoir were all classified as eutrophic, considering the chlorophyll-a concentrations;

The main optically active component in modelling the shape of the spectra in the aquatic system was chlorophyll-a;

It is possible to estimate chlorophyll-a concentrations in reservoirs of the semi-arid region using data from the MERIS orbital sensor;

The models displayed low values for absolute error in estimates of chlorophyll-a concentrations for a reservoir of the semi-arid region;

The models developed using simulated data from the MERIS orbital sensor for the attribute chlorophyll-a are reliable, showing that this variable can be measured remotely.

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