AN EMPIRICAL APPROACH FOR HYPERSPECTRAL REMOTE SENSING OF CHLOROPHYLL-A CONCENTRATION IN FUNIL HYDROELECTRIC RESERVOIR (RIO DE JANEIRO STATE, BRAZIL)

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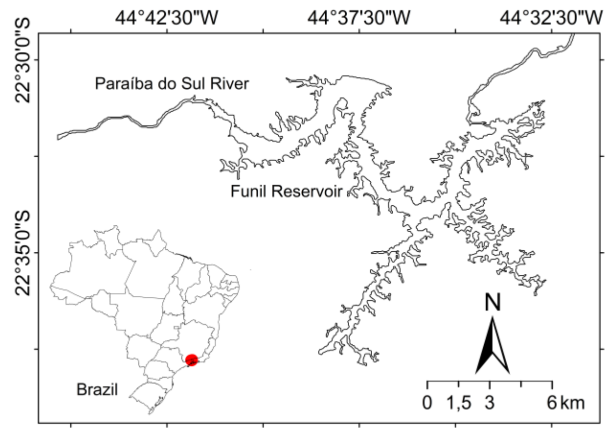
1. INTRODUCTION

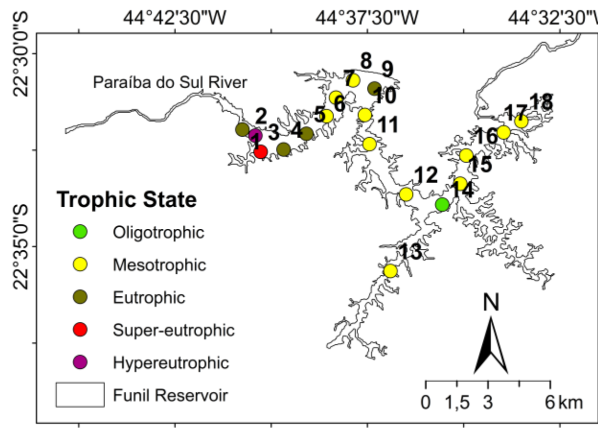
Chlorophyll-*a* (Chl-*a*) concentration is adopted as an indicator of water quality, especially of eutrophic stage. This information is useful for the management of water quality and the monitoring of water pollution. Traditional water quality monitoring is expensive and time consuming. These factors are particularly problematic if the water bodies to be examined are large. Moreover traditional techniques also bring about a high probability of undersampling. Conversely, remote sensing is a powerful tool to assess aquatic systems and is particularly useful in remote areas [1]. Models to estimate Chl-*a* concentrations are commonly empirically or semi-analytically based. Empirical approaches rely on a specific spectral feature, such as a spectral ratio modeled to biophysical measurements using statistical regression [2].

The objective of this work is to empirically search for best wavelength to develop statistical models to retrieve the Chl-*a* concentration in a tropical hydroelectric reservoir in Brazil.

2. STUDY AREA

The Funil hydroelectric reservoir is located in the middle course of Paraiba do Sul river, in Resende, Rio de Janeiro State - Brazil (22º 33' 48.97" S; 44º 36' 13.24" W, see Figure 1-a). Funil Reservoir was constructed during the late 1960s by the damming of the Paraíba do Sul River in Southeast Brazil. This hydrographic basin connects three economically important Brazilian states including Minas Gerais, Rio de Janeiro, and São Paulo. It serves as the primary source of drinking water for domestic supply, irrigation, industrial self-supply systems, aquaculture, and hydroelectric power generation. The eutrophication in this reservoir was increased by sewage disposal from one of the main Brazilian industrial areas in recent decades.





(a) (b)

Figure 1: Funil hydroelectric reservoir location (a) and the remote sensing reflectance (R_{rs}) and limnological data sampling sites (b). Each sample was classified according to their trophic state using [3] as reference.

3. DATA COLLECTION

The field campaign was carried out from 20 to 22 May 2012, when the reservoir's water level was high. In this field campaign proximal remote sensing and limnological data were collected.

3.1. Limnological Measurements

Water samples for laboratory analysis of Chl-*a* and total suspended sediment (TSS) were collected from 18 sampling sites (see Figure 1-b). The samples were kept at cool temperature and filtered on the same day. The TSS was determined based on [4], and Chl-*a* analyses were based on [5].

3.2. Proximal Remote Sensing Measurements

Remote sensing reflectance (R_{rs}) spectra were measured with TriOS hyperspectral radiometers RAMSES-ARC (upwelling radiance) and RAMSES-ACC (downwelling irradiance). These radiometers operates from 320 up to 950 nm of the electromagnetic spectrum with a spectral resolution of 3.3nm. The measurements were made by following the Ocean Optical Protocols by NASA [6]. The R_{rs} were collected in the same 18 limnological sampling sites (see Figure 1-b for location) and each sampled spectra was averaged by ten readings to minimize random effects.

4. DATA ANALYSIS

4.1. Empirical Models

The R_{rs} spectra were classified using the Spectral Angle Mapper (SAM) algorithm, which was used to separate these spectra into groups. Then, to develop the statistical models a regression test were used to compute the correlation between the two data sets (R_{rs} data and in-situ Chl-*a* measurements). Each group of R_{rs} spectra identified by SAM algorithm were processed to obtain a regression equation. This procedure will also allow the identification of the most correlated wavelength with Chl-*a*, through a simple regression procedure.

5. PRELIMINARY RESULTS

The R_{rs} spectra were classified into 3 groups using SAM method (see Figure 2). The group 1 contains 8 R_{rs} spectra, group 2 contains 5 R_{rs} spectra and group 3 contains 5 R_{rs} spectra.

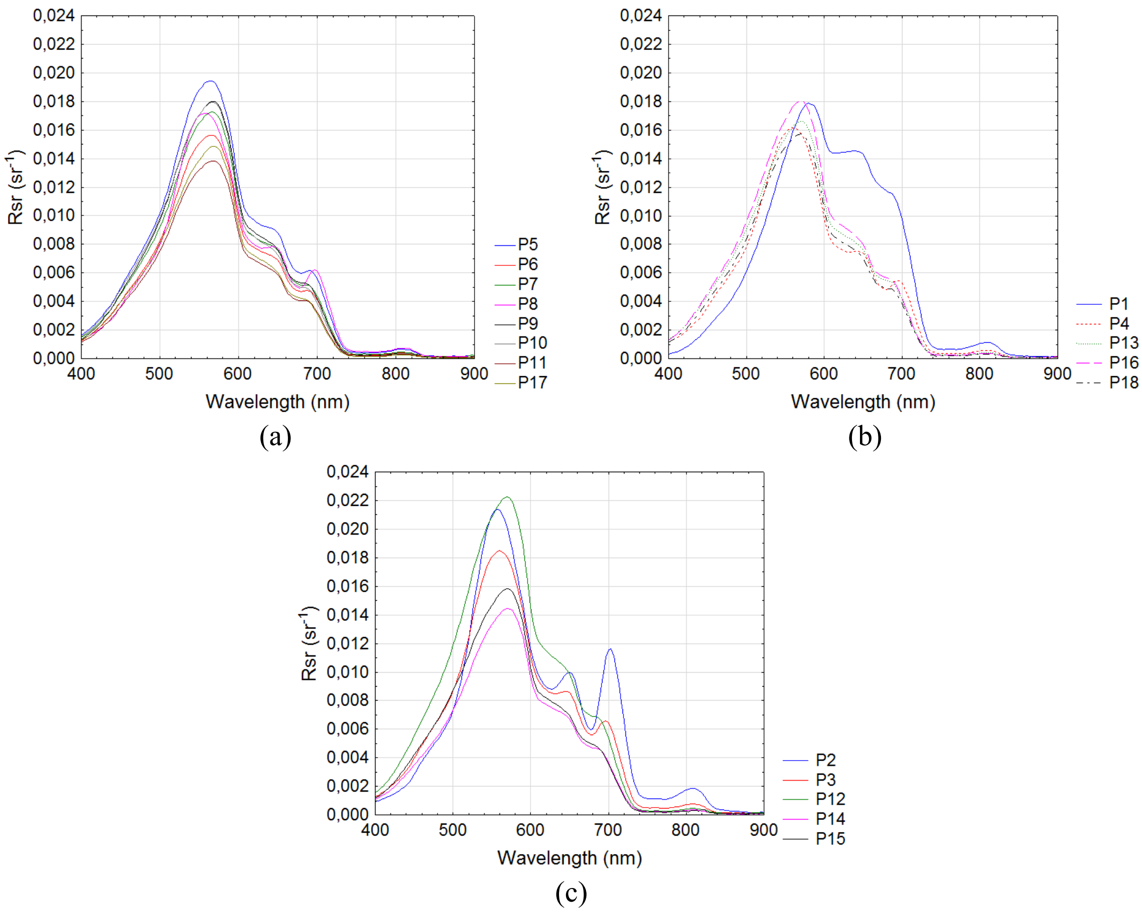


Figure 2: Remote sensing reflectance spectral classification using SAM algorithm. (a) group 1, (b) group 2 and (c) group 3.

The group 1 contains samples sites classified as oligotrophic and mesotrophic (see Figure 1-b); the group 2 contains samples classified as mesotrophic and eutrophic and group 3 contains samples classified from oligotrophic to hypereutrophic. The groups 1 and 3 (Figure 2-a and c) presents a peak of reflectance around 550 nm that is due to the increasing of scattering of light that increases the reflectance. In the group 2 (Figure 2-b) there is a shift of this peak to longer wavelengths, mainly due to the presence of higher concentration of inorganic matter; this is more distinguishable in sample P1 (hypereutrophic, see Figure 1-b). All this differences will influence the empirical models developed for each group.

The Table 1 shows information about the developed empirical models. The most correlated wavelength were 676,66 nm (r = 0,73), 873,33 nm (r = 0,93) and 820 nm (r = 0,99, for groups 1, 2 and 3, respectively. According to [7] the reflectance near 670 nm is governed by TSS, absorption by non-algal particles and CDOM in addition to Chl-*a*. The wavelength 820 nm and 873,33 nm are not commonly used to estimate Chl-*a* concentration in inland waters. However according to [8] there is a weak peak near 810 nm due to the algal cells backscattering combined with water absorption.

Table 1: Empirical models and the most correlated wavelength for each group of R_{rs} spectra.

Field Campaign	May		
Groups	Group 1	Group 2	Group 3
Coefficient of determination (R^2)	0,53	0,87	0,98
Wavelength (nm)	676,66	873,33	820
Number of spectra	8	5	5
r (95%)	0,73	0,93	0,99
Equation	$Chl-a = 6267 \times R_{rs(676.66)} - 22.169$	$Chl-a = 197175 \times R_{rs(873.33)} - 14.06$	$Chl-a = 169832 \times R_{rs(820)} - 57.446$

6. FINAL CONSIDERATIONS

The preliminary results shows that the SAM method was not suitable to adequately separate the groups in relation to the Chl-a (trophic stage); this is the case of group 3, with samples from oligotrophic to hypereutrophic waters. More work is necessary to better understand which method is the best to separate those spectra.

7. ACKNOWLEDGMENTS

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