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Short Communication

Spectral Properties Observations in Lakes of a Chilean National Park

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Abstract

Northern Chilean Patagonia has numerous pristine lakes associated with perennial native forests. The present study looks at optical properties in visible, close, and medium infrared wavelengths in mountain lakes of Alerce Andino National Park (41°S). These lakes have associated *Nothofagus* and *Fitzroya cupressoides* native forests of glacial origins. The results revealed high reflectance values for B1 and B3 for Chaiquenes, Triangulo, and Sargazo lakes located within *Nothofagus* and *F. cupressoides* native forest; Precipicio Lagoon has high B3, B4, B5, B6, and B7 reflectance values, perhaps due to granite surroundings; and the remaining 18 lagoons have relative low reflectance values for all bands, probably due to the predominance of Cupressaceae forest and mountains that make access difficult. These differences are associated with surrounding vegetation and geological characteristics of the studied sites.

Keywords: remote sensing, satellite images, lakes, oligotrophy

Introduction

The mountain lakes of Chiles Northern Patagonian Andes, specifically between 40-42°S, are oligotrophic, of glacial of volcanic origin [1], and are associated with native *Nothofagus* Blume forest – particularly *N. antarctica* (G. Forst.) Oerst., *N. pumilio* (Poepp. et Endl.) Krasser, and *N. dombeyi* (Mirb.) Oerst., and south of 41ºS the species *Cupressaceae* mainly *Fitzroya cupressoides* (Mol. Johnst.) gradually predominate [2-3]. From this viewpoint it would be possible to find differences in water quality associated with the surrounding basin properties that can be detectable using remote sensing techniques, such as those observed for Patagonian lakes [4-5].

The aim of the present study is to compare spectral properties data obtained from LANDSAT-8 images, with lakes and lagoons located within Alerce Andino National Park (41.5°-41.7°S and 72.36°-72.64°W), which is a mountain zone with native forest of *Nothofagus* that can be replaced gradually by Cupressaceae at southern latitudes and high altitudes in a pristine and unpolluted protected area [3].

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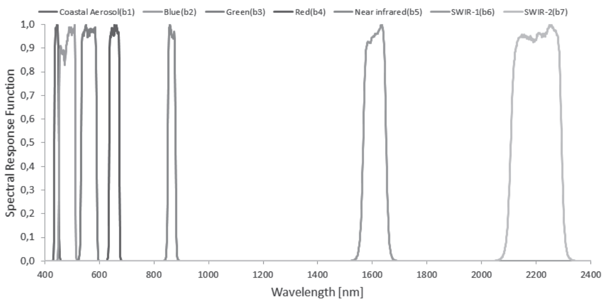

Fig. 1. Relative spectral response, sensor OLI/Landsat-8.

Table 1. Technical characteristics of the Landsat-8/OLI sensor reflective bands.

Band	Spectral Range [nm]	Wavelength Center [nm]	GSD [m]	Band Name
1	430-450	443	30	Coastal/ Aerosol
2	450-510	482	30	Blue
3	530-590	562	30	Green
4	640-670	655	30	Red
5	850-880	865	30	NIR
6	1,570-1,650	1,610	30	SWIR1
7	2,110-2,290	2,200	30	SWIR2

Material and Methods

In the remote sensing procedures, a LANDSAT-8 image, sensor Operational Land Imager (OLI) is used, dated from 13 February 2015. This image is provided by the Land Processess Distributed Active Archive Center (LP-DAAC) of the U.S. Geological Survey (*LPDAAC.usgs.gov*). The spectral and spatial characteristics of the OLI sensor are presented in Fig. 1 and Table 1. The bands of visible, near, and mid-infrared were calibrated radiometrically to spectral radiance and then to reflectance with atmospheric correction being applied.

The obtained reflectance of Alerce Andino National Park lakes (Fig. 2), from seven bands of OLI sensor, are presented in Table 2. In the reflectance data analysis we applied a principal correspondence analysis to obtain the grouping for sampled sites. This statistical analysis was applied using Analize-it software, based on methodology used for Patagonian lakes [5-6].

Results

The correlation analysis (Pearson correlation test) revealed only direct significant correlations between B1 with B3 (R^2 = 0.629; $p<0.05$), B1 with B4 (R^2 = 0.608; $p<0.05$), B3 with B4 (R^2 = 0.898; $p<0.05$), B3 with B5 (R^2 = 0.858; $p<0.05$), B3 with B6 (R^2 = 0.523; $p<0.05$), B4 with B5 (R^2 = 0.851; $p<0.05$), B4 with B6 (R^2 = 0.621;

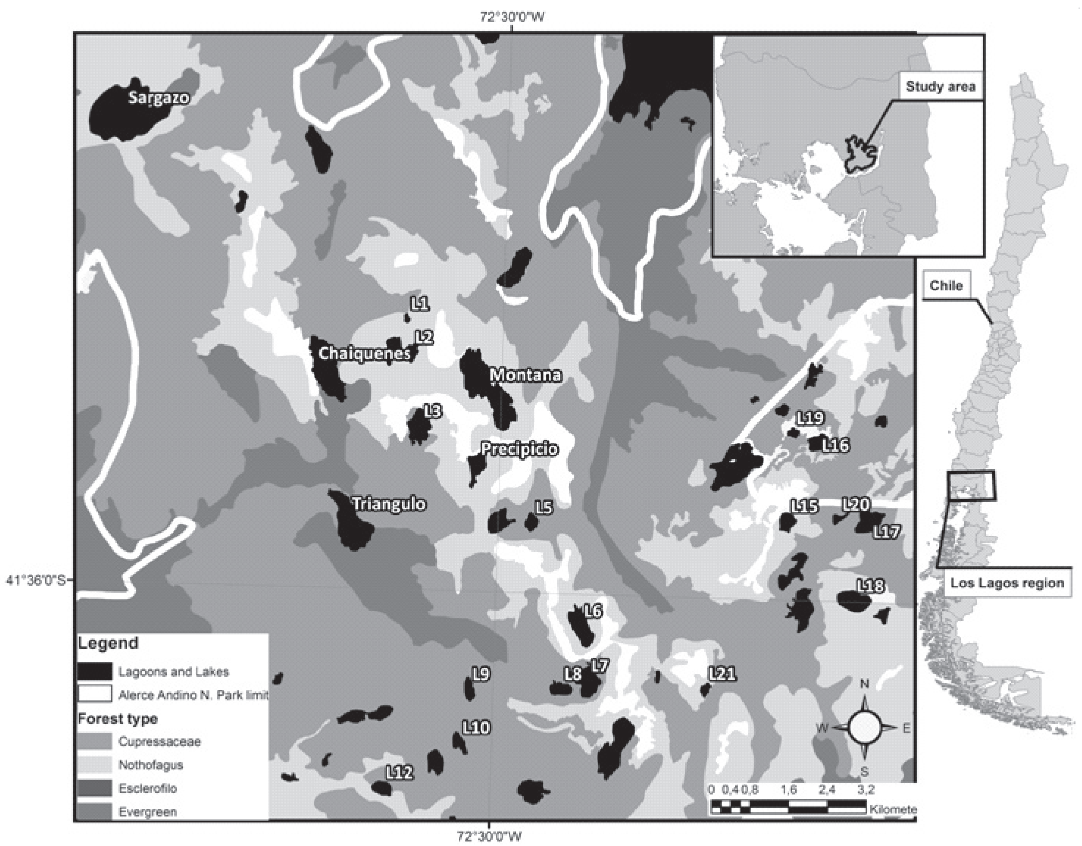

Fig. 2. Study area: Alerce Andino National Park, North Patagonia, Chile.

Table 2. Geographical location, altitude, and reflectance of studied lakes.

	Geographical location	Altitude m.a.s.l.	B1	B2	B3	B4	B5	B6	B7
Chaiquenes	41.5594 S; 72.5432 W	538	0.021168	0.015590	0.011889	0.006522	0.013080	0.005444	0.006007
L1	41.5494 S; 72.5240 W	1160	0.013288	0.009574	0.006870	0.002329	0.009202	0.004609	0.006052
L2	41.5556 S; 72.5227 W	1080	0.012691	0.009309	0.006943	0.002500	0.008693	0.004122	0.005443
L3	41.5693 S; 72.5201 W	1087	0.013940	0.010826	0.006870	0.002281	0.008184	0.003333	0.004902
L5	41.6055 S; 72.4789 W	1014	0.013886	0.010609	0.008853	0.003304	0.010196	0.004470	0.005489
L6	41.6156 S; 72.4768 W	966	0.016005	0.012342	0.007996	0.003134	0.009638	0.003959	0.005331
L7	41.6173 S; 72.4834 W	930	0.014212	0.105610	0.007237	0.002207	0.008790	0.003078	0.004857
L8	41.6179 S; 72.5062 W	832	0.014484	0.010416	0.007825	0.002890	0.009493	0.003774	0.005150
L9	41.6278 S; 72.5082 W	833	0.013180	0.009358	0.008192	0.003938	0.009953	0.004145	0.005293
L10	41.6366 S; 72.5269 W	991	0.013832	0.009839	0.007947	0.003914	0.009808	0.003495	0.005263
L12	41.5850 S; 72.4284 W	1183	0.013587	0.009767	0.007457	0.003207	0.009565	0.003797	0.005218
L15	41.5994 S; 72.4116 W	853	0.017500	0.012414	0.006527	0.001988	0.007069	0.004354	0.005579
L16	41.5685 S; 72.4277 W	996	0.013017	0.010080	0.008486	0.003061	0.010147	0.003147	0.005692
L17	41.5843 S; 72.4157 W	980	0.014484	0.010922	0.007359	0.002402	0.008911	0.003542	0.004834
L18	41.6165 S; 72.4476 W	1061	0.012718	0.009550	0.007164	0.002695	0.008838	0.003379	0.004789
L19	41.6171 S; 72.5536 W	924	0.013451	0.010994	0.009955	0.003572	0.010244	0.004191	0.005669
L20	41.5866 S; 72.4918 W	902	0.013968	0.010392	0.008682	0.003158	0.010656	0.004957	0.005421
L21	41.6170 S; 72.5535 W	925	0.015842	0.012342	0.008461	0.002451	0.010947	0.005003	0.005849
Montana	41.5702 S; 72.4214 W	1042	0.015815	0.012197	0.006949	0.002281	0.008329	0.003240	0.004970
Precipicio	41.5846 S; 72.4082 W	1028	0.017092	0.013304	0.011008	0.007180	0.014122	0.008391	0.008804
Sargazo	41.5125 S; 72.5951 W	354	0.019510	0.014122	0.010763	0.005157	0.010244	0.003287	0.004609
Triangulo	41.5880 S; 72.5365 W	285	0.017038	0.012317	0.009000	0.004328	0.009226	0.003333	0.004902

$p<0.05$), and B5 with B6 ($R^2 = 0.767$; $p < 0.05$) (Table 3). The PCA revealed that variables B3, B4, B5, and B6 contribute to axis 1, whereas B2 contributes to axis 2 (Table 4, Fig. 3). We also observed high reflectance values for B1, B2, and B3 for Chaiquenes, Triangulo, and Sargazo lakes located within *Nothofagus* and *Cupressaceae* native forests and 600 m lower. Precipicio Lagoon has high B3, B4, B5, B6, and B7 reflectance values, perhaps due to granite rocks in their surroundings. The remaining 18 lagoons with relative low reflectance values for all bands would be due to the predominance of *Cupressaceae* forest and mountains, where it is very difficult to access (lake altitudes 800-1,200 m).

Table 3. Correlation matrix for variables considered in the present study; values in bold denote significant correlation (p<0.05).

	B1	B2	B3	B4	B5
B6	0.308	-0.175	**0.523**	**0.621**	**0.767**
B5	0.402	-0.107	**0.858**	**0.851**	
B4	**0.608**	-0.143	**0.898**		
B3	**0.629**	-0.105			
B2	-0.002				

Discussion

The present study revealed differences in optical properties (reflectances) for studied lakes that were

Table 4. PCA contribution percentage of variables for axis 1 and 2.

	1	2
B1	-0.346	-0.332
B2	0.091	-0.910
B3	-0.486	-0.109
B4	-0.494	-0.041
B5	-0.484	0.040
B6	-0.396	0.216

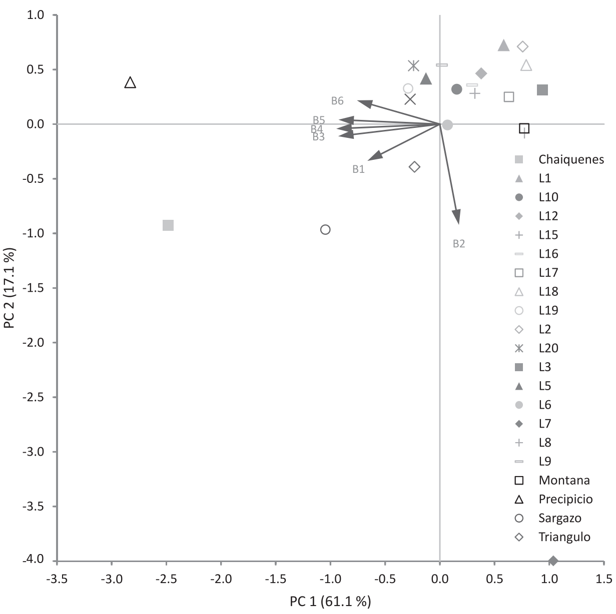

Fig. 3. PCA analysis for variables considered in the present study.

denoted using remote sensing techniques determined for Patagonian lakes with marked environmental heterogeneity such as were observed for Tagua Tagua and General Carrera lakes [4-6].

The environmental heterogeneity for Patagonian lakes has been described with details mainly in trophic status and associated basins [7-9], but recently optical properties associated with ecological implicances due to the presence of associated glaciers with consequent changes in water coloration properties, light absorption, and changes in associated trophic webs have been studied [10-12], and these results can be associated with optical properties obtained from satellite images [4-6]. Many of these lakes are located in zones with serious accessibility issues, and only a few of them are not accessible by mountain paths [1, 3]. Then many of these lakes are located in zones without easy access, and in this scenario the first exploration by remote sensing techniques would be very useful for beginning limnological studies [12-15].

The results presented indicate that a potential correlation between environmental associations due to surrounding basins and optical properties might possibly be found; however, it would be necessary to carry out more intensive studies and obtain more data to be able to confirm or discount the possibility of finding potential correlations and their variations at multiple spatial and temporal scales [15-17].

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