

Freshwater ecosystems' contributions to people: a social media analysis of aquatic environments in Tucumán (Argentina)

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Abstract – Environmental management requires understanding nature's multiple values, but capturing diverse perspectives can be challenging. Social media provide user-generated data that complement traditional approaches. Using Google Maps and YouTube, we conducted a sociocultural valuation of freshwater ecosystems in Argentina's Tucumán province. We assessed 1,338 images from 54 sites to determine (i) depiction of ecosystems and socio-environmental problems; (ii) users' age profile, uses, and activities in these spaces; (iii) portrayal of nature's contributions to people (NCP) and associated values; and (iv) geographic distribution NCP and values and related accessibility of sites. Most images depicted rivers and waterfalls (88% of images; 89% of sites), primarily in the Yungas ecoregion (99% of images; 94% of sites). Half of images (50%) and 87% of sites showed freshwater ecosystems with human uses and activities, mostly in the context of passive leisure (72% of images; 63% of sites). Activities that physically engaged with nature were less frequent and included fishing (7%), trekking (6%), kayaking (5%), and cycling (2%). Consequently, non-material NCP—especially aesthetic and naturalistic values—dominated the representations (97% of images; 98% of sites). Negative values were uncommon (1% of images; 28% of sites), mostly associated with the Plain regions. Finally, spatial trends were not a function of nearness to roads and population centers, as the Yungas ecoregion was clearly more depicted in social media, despite being less accessible. These findings enhance understanding of people-nature relationships in aquatic ecosystems and can inform monitoring strategies based on relational values, which complements mainstream foci on intrinsic and instrumental values.

Keywords: aquatic ecosystems / ecosystem services / nature's contributions to people / plural valuation / sociocultural valuation

1 Introduction

The 'relational' turn in sustainability (West *et al.*, 2020) and the shift towards more 'inclusive' conservation (Anderson, 2025) demand new approaches to account for diverse values in

people-nature interactions. Global environmental change affects both ecological and social systems (Bennett *et al.*, 2016). In particular, the drivers of urbanization and technological shifts have heightened concerns about the loss of experiences with and disconnection from nature (Gaston and Soga, 2020). For example, freshwater ecosystems are highly vulnerable to environmental degradation and also contribute to vital components of human well-being, including

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water, food, energy, recreation, aesthetics, and cultural experiences (Nicolás-Ruiz *et al.*, 2024). Understanding these ecosystems from a plural perspective requires context-specific knowledge that complements conventional scientific approaches (Díaz *et al.*, 2018).

Today, over half of the world's population is active on social media (DataReportal, 2021), and user-generated content—photographs, videos, and comments—provides detailed spatiotemporal information on people–nature interactions and nature's contributions to people (NCP) (Zhang *et al.*, 2022; Da Silva *et al.*, 2024). Analyses of such content have been used to monitor not only environmental conditions, but also identify recreational activities and assess which NCP are engaged by people (Kalous *et al.*, 2018; Rossi *et al.*, 2020; Oteros-Rozas *et al.*, 2018; Clemente *et al.*, 2019). Jarić *et al.* (2020) define these uses as iEcology and culturomics, respectively, emphasizing their potential to integrate social media into aquatic ecosystem research and management. Social media can reveal both spatial patterns and qualitative aspects of these people–nature relationships, including biodiversity components, landscape features, and emotional responses elicited by nature (Willemen, 2020; Fox *et al.*, 2021; Da Mota *et al.*, 2022). For example, previous research has shown that rivers and lakes are valued for aesthetic and recreational experiences, but are also prone to anthropogenic (*e.g.*, contamination) and natural (*e.g.*, flooding) pressures (Van Berkel and Verburg, 2014; Khan *et al.*, 2022; Da Silva *et al.*, 2024).

While surveys and interviews remain widely used to evaluate people–nature relationships (Chai-Allah *et al.*, 2023), visual methods using photographs and videos have emerged as valuable tools to capture both subjective experiences (*e.g.*, inspiration, relaxation) and material benefits (*e.g.*, food, water) (Wylie, 2007; López-Santiago *et al.*, 2014). Jarić *et al.* (2020) propose extending social media data—previously applied mainly in terrestrial contexts—to aquatic environments, highlighting applications in species monitoring, ecosystem assessment, wildlife and fisheries management, identification of flagship and umbrella species, protected area management, and social impact assessment. In this way, social media can inform the protection of biodiversity components critical to people and reveal broader people–nature relationships and values (Kellert, 2008; Kelemen *et al.*, 2014). In this way, social media can ultimately support designing more plural approaches to environmental research and management that consider heterogeneity in perceptions and uses of nature, shaped by local social-ecological conditions (Buijs *et al.*, 2009; Díaz *et al.*, 2015).

In this study, we treated social media posts as an “online suggestion box” reflecting users' evaluations of and interactions with nature (Ghermandi and Sinclair, 2019). We focused on Google Maps and YouTube, platforms previously applied to study people–nature interactions in diverse ecosystems (Oteros-Rozas *et al.*, 2018; Rossi *et al.*, 2020; Barros *et al.*, 2022). Using these sources, we conducted an exploratory sociocultural valuation of freshwater ecosystems in Tucumán province, Argentina, assessing (i) ecosystems and socio-environmental issues represented; (ii) user age profiles, uses, and human activities; (iii) NCP and associated values; and (iv) image distribution across biogeographic zones (Brown and Pacheco, 2006) and in terms of accessibility from roads and population centers.

2 Materials and methods

2.1 Study area

Tucumán is a province in northwestern Argentina characterized by a range of geographical areas and ecoregions. In the plains we find the Semiarid Chaco and the Foothill Forest of the Yungas (now transformed into a transitional area), while the mountainous regions encompass the Yungas ecoregion (with three altitudinal zones: High and Low Montane Forests and Fog Grasslands), as well as the Monte of Sierras and Bolsones, and the High Andes ecoregions (Brown and Pacheco, 2006). This area is crossed by rivers that originate in the western mountains, fed by meltwater and precipitation, and run eastward, where water inputs are scarce, spreading into a vast plain (Díaz Achával, 2017). The Salí-Dulce basin is the province's largest watershed, characterized by alternating high (summer-autumn) and low water flow (winter-spring) (Ruiz and Busnelli, 2014). During the high-water season, torrential rain events often result in flooding.

The population within this basin totals 1,428,719 inhabitants (INDEC, 2010), which represents 82% of the total population of Tucumán Province. Of this population, 233,169 have unmet basic needs and are living in structural poverty. Additionally, 742,030 residents lack access to sewage systems, and 159,870 people lack access to running water (INDEC, 2010). The primary economic activities in the upper basin are agriculture and livestock, with significant industrialization, particularly related to sugar mills, alcohol distilleries, citrus processing plants, and slaughterhouses, which account for 65% of the region's businesses. The main crops are sugarcane and citrus trees, alongside smaller-scale production of tobacco, corn, wheat, soybeans, potatoes, and chickpeas. There is also extensive livestock grazing, as well as cattle feedlots, pig farms, and poultry farms (Díaz Achával, 2017). In contrast to basins' headwaters, the middle and lower river reaches are less industrialized and rely more on agriculture and ranching. Due to water scarcity, these activities depend heavily on artificial irrigation and use of river water. Evidence suggests that most rivers in Tucumán are affected by water pollution from urban and industrial activities (Fernández, 2017). The main sources of water pollution in the basin include sugar and paper mills, citrus processing plants, textile factories, slaughterhouses and sewage effluents (Díaz Achával, 2017).

2.2 Data collection

Social media platforms can be preferred by certain user profiles, making the selection important. We chose Google Maps and YouTube due to their broad popularity and use across society. We considered other social media sites reported in the literature, but did not include them due to a lack of data in Tucumán, particularly Flickr (Martínez Pastur *et al.*, 2016; Van Zanten *et al.*, 2016; Vidal Llamas *et al.*, 2024) and Panoramio (which was closed in 2016 and much of its data were later integrated into Google Maps, Zhang *et al.*, 2022; Ghermandi *et al.*, 2023). For its part, Google Maps is a web-based geospatial application that offers scrollable maps and satellite photos of the world; it is easy to use and accessible to anyone with a smartphone. Meanwhile, YouTube is a website with over a billion users worldwide (<https://www.youtube.com/yt/>

Table 1. Variables coded from photograph and video images uploaded by users to Google Maps and YouTube of freshwater ecosystems in Tucumán province (Argentina). The information below includes the definition, categorization, and examples of each analytical variable as applied to the 1,338 images assessed in the database for the period 2012 and 2022.

Variable	Definition	Categories and examples
Source	Platform from which data were collected	<i>YouTube</i> <i>Google Maps</i>
Data type	The format of the image recorded	<i>Video</i> <i>Image</i>
Aquatic habitat	Freshwater ecosystem represented	<i>Lentic</i> : reservoir (with lake). <i>Lotic</i> : river, stream, waterfall
Biogeographic zone	Ecoregions as per Brown and Pacheco, (2006)	<i>Mountain</i> : Fog grasslands and Low and High Montane Forest areas of Yungas <i>Plain</i> : Foothill Forest of Yungas and Semiarid Chaco
Uses and activities	Passive uses related to contemplative enjoyment or relaxation Active uses related to sports and other physical activities	<i>Leisure</i> : drinking <i>yerba mate</i> , having <i>asado</i> (barbecue), admiring nature, sharing with friends and family. <i>Recreation</i> : kayaking, fishing, trekking, horseback riding, paragliding, biking
Nature's contributions to people (NCP)	All contributions, both positive and negative, that people obtain from nature (Diaz et al., 2018)	<i>Material</i> : Food, materials (e.g., for construction). <i>Non-Material</i> : Learning and inspiration; physical and psychological experiences <i>Regulation</i> : Quantity of flow and regime of freshwater, maintenance and refuge for animals and plants
Typology of values	Ten categories of nature-based values, considered to have an adaptive function in the context of human dependence on the natural world (Kellert, 2008; 2012)	<i>Aesthetic</i> : Appreciation of the physical appeal and beauty of nature <i>Naturalistic</i> : Enjoyment of immersion in nature <i>Utilitarian</i> : Benefits from the practical use and material exploitation of nature <i>Negativistic</i> : Fear, aversion, alienation from nature. <i>Humanistic</i> : Strong emotional attachment and “love” for aspects of nature. <i>Moralistic</i> : Ethical concern for nature.

[press/statistics.html](#)) that has become very popular not only for posting personal experiences, but as an information source (e.g., tutorials). This platform is mainly dedicated to sharing videos and is accessible to any user. Creating a database from both platforms gave the potential of assessing a wider range of user profiles and increased the number of images available.

To create our database, we searched for photographs and videos (collectively referred to throughout as ‘images’) uploaded to these platforms between 2012 and 2022. Image searches were conducted in Spanish with phrases like “___ de Tucumán” (___ of Tucumán), where the space was filled with terms including *rios* (rivers), *arroyos* (stream), *cascadas* (waterfalls), and *embalses* (dam-created lake). A total of 1,450 images were recorded at 54 sites that were at least 1 km from each other and distributed throughout the province of Tucumán. Since our goal was to determine an individual's subjective experiences of nature, we removed images that were curated by newspapers and groups dedicated to specific activities like fishing and water sports. Additionally, images from the same user within a 24 h period for the same site were removed to ensure statistical independence for each image (i.e., one image = one replicate). Images deemed ineligible for

assessment totaled 112. The remaining database of 1,338 images was constituted of 1,183 Google Map photographs and 155 YouTube videos.

We coded each image for the following variables: source type, data type, type of aquatic environment, environmental problems/issues observed, user age group, uses and activities identified, and NCP represented and values expressed (see [Tab. 1](#) for details). Additionally, we included the information generated by users from georeferenced images with attached keywords (tags), which enhanced our ability to interpret values that are difficult to extract automatically through visual content recognition alone ([Richard and Friess, 2015](#)). Tags capture what people who visited a landscape and shared images considered noteworthy, thus providing direct information about people-nature relationships. All attributes were classified based on their apparent content ([Sherren et al., 2017](#)). While there are other classifications (e.g., [Pascual et al., 2017](#)), we chose the values typology proposed by [Kellert \(2008, 2012\)](#) because it categorizes a wider range of values and defines specific details that proved more suitable in pilot efforts to classify the content found in the database, ultimately representing six of this typology's 10 categories. Finally, based on experiences from

Table 2. Number of sites (and number of images) for each variable assessed from social media images in Google Maps and YouTube regarding freshwater ecosystems of Tucumán province, Argentina. Data are displayed per ecoregion with two geographic areas (mountains, plains) and the totals.

Variable	Category	Mountains			Plains		Total
		Fog grasslands	High Montane Forest	Low Montane Forest	Foothill Forest	Semiarid Chaco	
Ecosystem	<i>Lotic</i>	5 (38)	23 (624)	8 (198)	12 (56)	3 (18)	51 (934)
	<i>Lentic</i>	1 (268)		2 (136)			3 (404)
Uses and activities	<i>Active</i>	2 (14)	9 (65)	5 (41)	12 (26)	3 (8)	31 (156)
	<i>Passive</i>	6 (68)	9 (123)	4 (29)	6 (93)	9 (36)	34 (349)
Users	<i>Children</i>	2 (16)	5 (41)	1 (23)	8 (19)	2 (8)	18 (107)
	<i>Adults</i>	5 (93)	15 (188)	1 (32)	17 (220)	3 (5)	41 (538)
	<i>Senior citizen</i>	2 (3)	2 (3)	1 (2)	3 (4)	1 (1)	9 (13)
Problems	<i>Pollution</i>				2 (2)	1 (1)	3 (3)
	<i>Flooding</i>				6 (9)	6 (8)	12 (17)

similar studies involving photographic content analysis (Barry, 2014; Van Zanten *et al.*, 2016), we included a set of landscape indicators that could be determined visually like what species or habitats are being represented.

2.3 Data analysis

We calculated absolute abundance and relative frequencies of studied variables and conducted descriptive statistics expressed as number of sites and number of images per site per biogeographic area (Tab. 2). We used an alluvial diagram to assess the proportion of images belonging to (i) type of aquatic environment, (ii) biogeographic area, and (iii) NCP. Each value type was assigned a color in the diagram, providing an interpretation of how values are distributed across these ecological and geospatial categories. The alluvial diagram was created using the ‘ggplot2’ and ‘ggalluvial’ packages in R software, version 4.2.0 (R Core Team 2022).

To locate their biogeographic distribution, we determined the relative frequency of values as plotted on a map. To further facilitate data visualization, in areas with high site density, centroids were calculated for sites within 5 km of each other, aggregating all evaluations corresponding to these centroids. The size of circles on the map was represented logarithmically due to the large difference between the most representative evaluation (with 517 cases) and the average frequency of the rest (ranging from 1 to approximately 25 cases). We mapped the geographic zones and ecoregions where the sites with the highest preferences by users were found. The map creation and incorporation of pie charts were performed using QGIS software.

To complement this spatial analysis, we also quantified accessibility of sites portrayed in social media. Accessibility was calculated as the total travel time along the OpenStreetMap (OSM) road network, assuming travel by car, plus the walking time for the final segment from the nearest road network node to the centroid of each grid cell (1.5 × 1.5 km), using a walking speed of 4.5 km/h. Urban origins were defined as the localities of San Miguel de Tucumán, Yerba Buena, Concepción, Tafi del Valle, Monteros, and Aguilares. For each

cell, we used the minimum travel time among these origins, assuming that visits originate from the nearest city. Accessibility time was classified into fixed intervals: <20, 20–45, 45–90, and >90 min. Finally, an empirical cumulative distribution function (ECDF) of accessibility was computed for the Yungas and for the Plains (Foothill Forest and Semiarid Chaco), normalized within each group, to summarize the continuous distribution of travel times and to compare whether highly valued sites in each ecoregion occur at systematically different levels of accessibility.

3 Results

3.1 Ecosystems and environmental problems

The search and selection criteria yielded a total of 1,338 images (1,183 photographs from Google Maps and 155 videos from YouTube). Based on the georeferenced photos in Google Maps, we identified 54 sites where images were taken, most of which were of lotic ecosystems (70% of images, 94% of sites) (Tab. 2). There were few lentic ecosystems (only 6% of sites). All of these were dam-made reservoirs, but were intensively represented (30% of images). Overall, we found that relatively few sites concentrate the majority of the images; just 17 of 54 sites had 90% of images. In particular, reservoirs and waterfalls were highly represented (median images per each of these types of sites was 134 and 53, respectively). Rivers also showed substantial coverage, with a median of 4 images per site; additionally, 42 river sites had more than 10 images.

Overall, images depicting environmental problems were rare (1% of images), but they were present at 26% of sites. However, these factors were only represented in plains rivers and portrayed flooding/overbank inundation, which is at least partially a natural phenomenon, and fish kills (dead fish along riverbanks), which are consistent with pollution or illegal fishing.

3.2 Users, uses, and activities

People were depicted in 49% of images at 76% of sites. Among these images, the majority were adults (18–60 yr; 82%), followed by children (16%) and senior citizens (2%)

(Tab. 2). Despite these trends, it is important to note that all age groups were represented. Within the adult and senior categories, heterogeneous social groups were included, such as families, couples, and groups of hikers, cyclists, and fishermen, among others.

Most assessed images depicted freshwater ecosystems in the context of human uses and activities (50% of images, 87% of sites). The primary use was for leisure activities (72% of images, 63% of sites), which were done alone or collectively and included mostly passive uses of nature. Examples include contemplation and enjoyment while sharing a meal or drinking *yerba mate* (a type of tea sipped through a filtered straw in a communal recipient) on the water's edge, individuals admiring nature, and groups of friends spending time together. The less frequent categories were mostly active recreational activities that included, fishing (7% of images, 11 sites) trekking (6% images, 7 sites), kayaking (5%), children playing (4%), and cycling represented 2% of the images. Less-common active pastimes were horseback riding, paragliding, boat rides, dancing, soccer, and motorcycle racing (together totaling 3%). Finally, the least represented activity observed in images was related to extraction of materials like sand and gravel for work-related activities (1%).

3.3 Contributions and values

All images were interpreted as representing at least one NCP. The vast majority depicted non-material NCP (96.5%), mostly regarding physical experiences through various water-related activities and sports (*e.g.*, recreation) and also psychological experiences and inspiration (*e.g.*, relaxation). Meanwhile, the other categories were rather infrequently seen in the database (3% regulating NCP; <1% material NCP). The most documented regulating NCP had to do with the water cycle. These NCP highlighted predominantly negative contexts, showcasing river floods and overflow events, but also many could be interpreted as evidencing the creation and maintenance of habitats for animals and plants (*e.g.*, those photos taken specifically of animals or plants located in these environments). With regards to material contributions, there were only two representations: fish as food and sand being extracted as a material resource.

From the uses and NCP found in these images, we interpreted six out of 10 possible categories described by Kellert (2008, 2012). We found no instances of explicitly dominionistic, ecologicistic-scientific, spiritual, or symbolic values. The most documented values were aesthetic (66% of images, 63% of sites), represented by images taken to capture beautiful landscapes (*e.g.*, sunsets). Second were images depicting naturalistic values (32%), which were often about engaging in diverse outdoor activities and passive uses such as relaxation and enjoyment. Negativistic values accounted for just 1% of images, but this value type was mainly featured in images of river floods and overflow, along with references to illegal fishing and river pollution. Lastly, the least represented values were humanistic, utilitarian, and moralistic, each below 1%. These relational values (*e.g.*, humanistic, moralistic) were interpreted as representing feelings of love and ethical concern for nature (*e.g.*, people cleaning up and removing trash or plastics from these sites). Meanwhile, the instrumental values

(utilitarian) were about food (*e.g.*, fish) and materials (*e.g.*, extraction of gravel for construction).

3.4 Distribution and accessibility

Considering both the frequency and distribution of freshwater ecosystem values across the province, we found that images in the Yungas ecoregion mostly depicted aesthetic values, followed by naturalistic values. Across both mountains and plains, lotic habitats were the most represented in photos and videos, compared to lentic environments which were less common. Furthermore, negativistic values were observed exclusively in images of rivers located in the central-eastern plains (Foothill Forest and Semiarid Chaco ecoregions), mainly reflecting problems with regulating contributions related to waterflow (*i.e.*, flooding) (Figs. 1 and 2).

Images of aquatic environments were recorded in almost all the ecoregions of the province. Only High Andes and Monte of Sierras and Bolsones ecoregions had no images of freshwater ecosystems (at least in these two social media platforms). In contrast, most images were concentrated in the Yungas (High and Low Montane Forest), and Foothill Forests. To a lesser extent, there was a depiction of aquatic environments in the Semiarid Chaco (plain) (Fig. 3).

The accessibility analysis revealed that sites with more images were not the most accessible. For example, the Yungas ecoregion concentrated the majority of photographs, but mostly in sites with low to intermediate accessibility, while the Plains contributed only a small fraction of images, but across all categories (Fig. 4). The empirical cumulative distribution function (ECDF) of accessibility showed that the Yungas curve was shifted to the right relative to that of the Plains, indicating lower overall accessibility in the Yungas region (Fig. 5). For example, in the Yungas nearly all images had intermediate levels of accessibility (59% within 20–45 min range, 41% within the 45–90 min range). In contrast, in the Plains, 53% of images were within the <20 min range, 17% in the 20–45 min range, and 30% in the 45–90 min range.

4 Discussion

4.1 People-nature relationships with freshwater ecosystems

Although some studies have addressed the perception and valuation of aquatic ecosystems in Argentina (Zagarola *et al.*, 2014; Mastrandrea *et al.*, 2019; Graziano *et al.*, 2021), this research represents a pioneering contribution to the study of the social dimensions of these ecosystems in Tucumán and the broader northwest region. Based on user-generated content, this sociocultural valuation complements previous assessments of river conditions conducted through physicochemical (Hidalgo *et al.*, 2006), biological (Domínguez *et al.*, 2020), and survey-based approaches (Alberti *et al.*, 2024). Unlike earlier studies that emphasized negative perceptions of rivers—associated with sugar mills—social media data revealed predominantly positive associations between people and aquatic environments. In particular, the high social valuation of rivers and waterfalls in the Yungas region underscores the importance of promoting suitable spaces for their enjoyment and conservation.

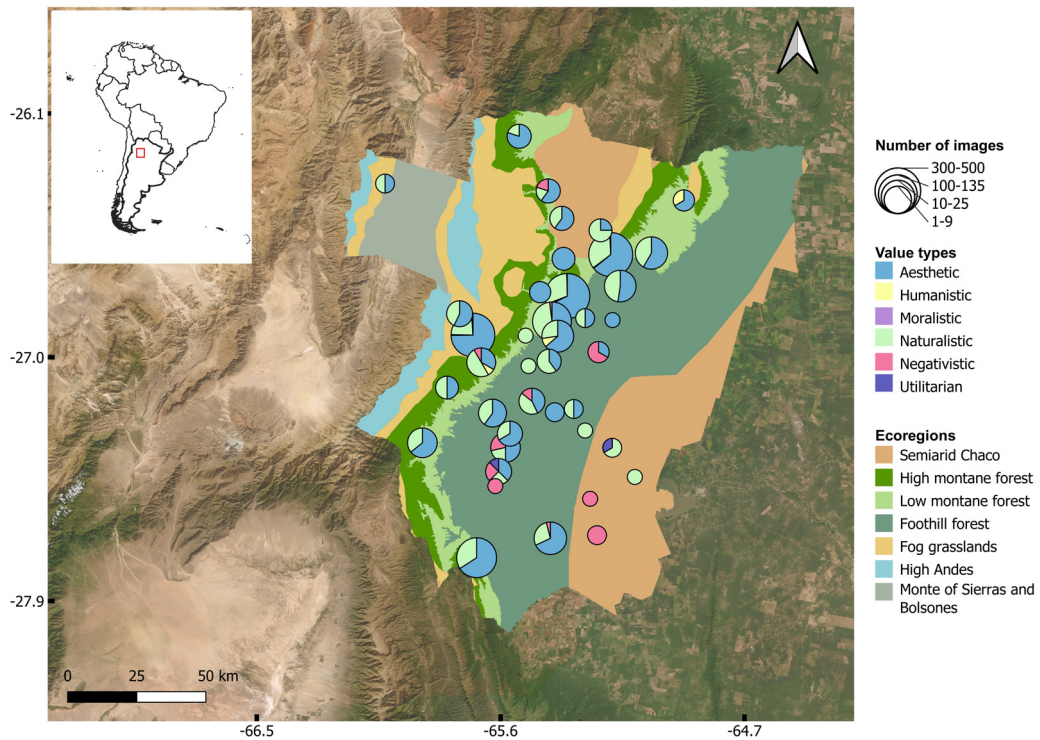


Fig. 1. Location and proportion of the values represented in social media images of freshwater ecosystems recorded in Tucumán province, Argentina from Google Maps and YouTube. Circle size indicates the number of images recorded per site.

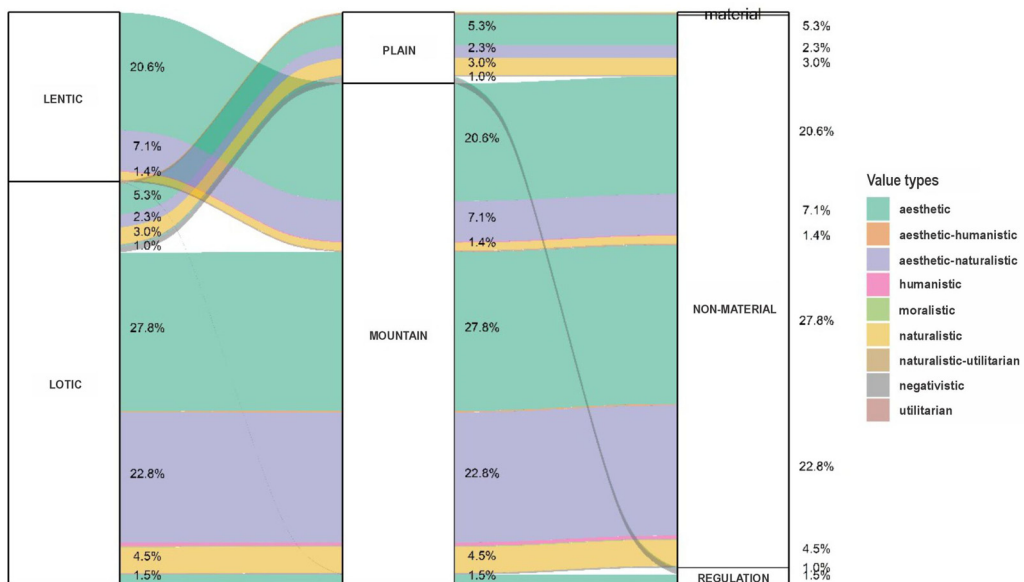


Fig. 2. Alluvial chart illustrating the proportion of images belonging to the two categories of aquatic ecosystems (lotic, lentic), geographic zone (mountain, plain), and the categories of nature's contributions to people (NCP: material, non-material, regulating). Colors represent types of values according to Kellert (2008, 2012).

Recreational and leisure activities were the most highly valued uses, reinforcing the need to integrate these dimensions into the planning of protected areas, especially those located along lowland rivers. While many protected areas primarily focus on species and ecosystems, this study demonstrates that

people also seek other forms of engagement that can, in turn, enhance their support for traditional biodiversity conservation. As noted by the IUCN (Leung *et al.*, 2018), many protected areas depend economically on tourism, and improving visitor experience and education is crucial to broader conservation



Fig. 3. Sites with the highest number of images and values represented by users on Google Maps and YouTube.

goals. Consistent with [Jarić *et al.* \(2020\)](#), these results support the use of social methodologies to foster greater public integration in the management of aquatic ecosystems.

In line with studies from other regions ([Oteros-Rozas *et al.*, 2018](#); [Clemente *et al.*, 2019](#)), physical and emotional experiences in nature—especially in landscapes with aquatic features—were the most frequently represented on social media, reflecting the relational values linked to non-material contributions of nature to people ([Ghermandi *et al.*, 2023](#); [Raymond *et al.*, 2023](#)). Among the most common cultural practices observed were social gatherings to share *mate* (traditional infused yerba mate drink) and *asados* (barbecue), both deeply rooted in Argentine culture. However, values related to the mere existence of nature and cultural heritage were underrepresented ([Richards and Friess, 2015](#)). Negative perceptions were less frequent and mainly associated with natural disturbances such as flooding, whereas few posts mentioned environmental problems like pollution, waste, or insecurity ([Alberti *et al.*, 2024](#)).

The highest concentration of images and associated values occurred in the mountainous areas of the Yungas, decreasing toward the lowland regions (Foothill Forest and Semiarid Chaco). This pattern appears counterintuitive if one assumes that visits—and consequently, user valuations—are primarily determined by ease of access, given that rivers in the plains are

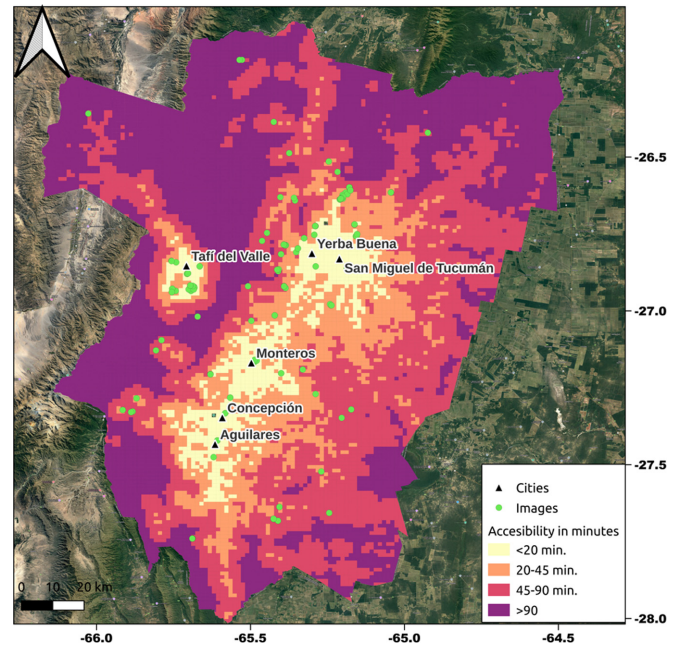


Fig. 4. Spatial distribution of accessibility in Tucumán, Argentina, expressed as total travel time (minutes) from the nearest major city along the road network plus a final walking segment to each 1.5 × 1.5 km grid cell. Colors indicate accessibility classes (<20, 20–45, 45–90 and >90 min); black triangles show urban origins and green dots indicate image locations.

typically closer to cities and roads, whereas Yungas rivers tend to be more conserved, more diverse, but located farther from urban centers. Our accessibility analysis shows that sites in the Yungas typically require longer travel times than rivers in the plains, yet they still concentrate most photographs and positive evaluations. This suggests that, for these river landscapes, perceived environmental quality and immersion in more natural settings can outweigh travel-time costs, in line with findings from other South American case studies (*e.g.*, [Martínez-Harms *et al.*, 2018](#)). At the same time, some dimensions of people-nature relationships (*e.g.*, spiritual, identity-related or explicitly negative values) were weakly represented in the analysed platforms. Visual social media tend to favor aesthetic and recreational content and specific user profiles, so our approach likely underestimates other ways in which rivers matter to local communities. Future research could incorporate additional platforms, such as Instagram, Facebook or TikTok, to capture a broader range of relationships and perceptions ([Šmelhausová *et al.*, 2022](#); [Tscholl and Sturm, 2022](#)) or combine social media with surveys and qualitative methods to develop a more causal understanding of how different groups value and use these ecosystems.

4.2 Towards more inclusive environmental management

Although social media data have inherent biases—such as the overrepresentation of younger or wealthier users ([Martínez-Harms *et al.*, 2018](#); [Jarić *et al.*, 2020](#))—they remain valuable for understanding people-nature relationships and NCP ([Cord *et al.*, 2017](#)). This sociocultural valuation of rivers

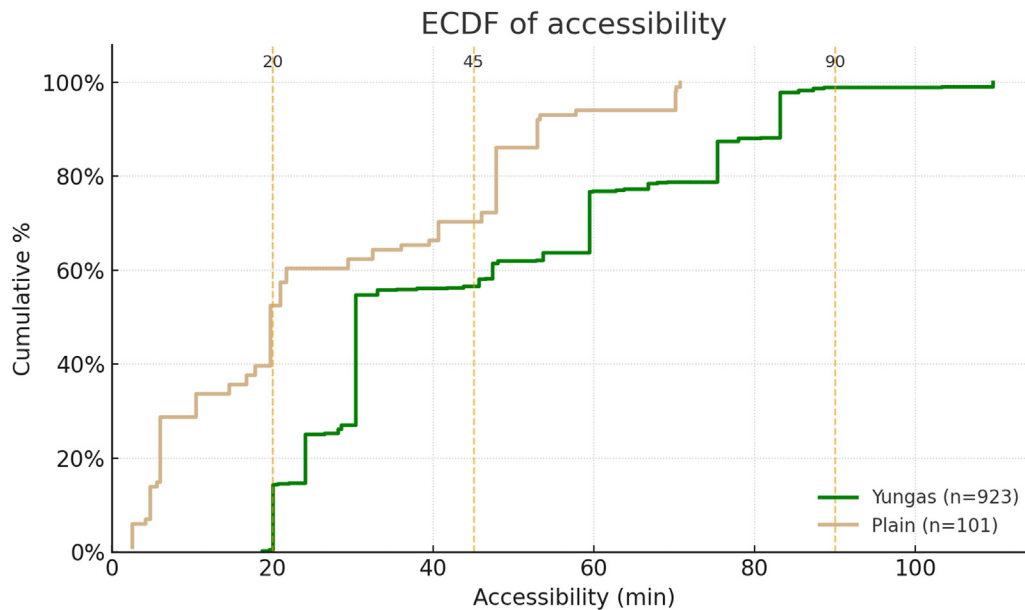


Fig. 5. Empirical cumulative distribution of accessibility for images located in the Yungas forest (green, $n=923$) and the Plains (Foothill Forest and Semiarid Chaco; brown, $n=101$). The y-axis shows the cumulative proportion of images that can be reached within a given travel time. Vertical dashed lines indicate the thresholds used to define accessibility classes (<20, 20–45, 45–90 and >90 min).

and lakes in Tucumán provides insights for understanding in terms of how different social groups benefit from aquatic ecosystems and highlights the predominantly positive ways in which these environments contribute to human well-being (Huang *et al.*, 2013; Dunkel, 2015).

The results of this study reveal both consistencies and contrasts with previous research on the social valuation of freshwater ecosystems in Argentina. In agreement with Mastrandrea *et al.* (2019), our findings highlight the central role of urban aquatic environments as spaces for recreation, aesthetic appreciation, and daily interaction with nature. However, our analysis broadens this perspective to encompass a wider geographical range, including both mountain and lowland areas. Similarly, in line with Graziano *et al.* (2021), our results identified socio-environmental issues affecting these ecosystems that compromise their integrity and conservation, underscoring the need to deepen our understanding of human–environment relationships. While Zagarola *et al.* (2014) examined perceptions of Patagonian watersheds using traditional survey methods, our study relies on social media data, which enable access to more spontaneous and contemporary cultural expressions of human–nature relationships. Both studies, together with that of Martínez Pastur *et al.* (2016), revealed that non-material NCP are the most highly valued by the community. However, unlike Martínez Pastur *et al.* (2016), our findings show that even in areas subject to higher anthropogenic pressure, non-material contributions remain dominant, suggesting a persistent and widespread social appreciation of fluvial environments. Overall, these studies highlight the importance of integrating sociocultural approaches—whether through participatory methods or digital data analysis—to foster more inclusive and plural management of freshwater ecosystems.

In this regard, our study broadly supports global calls for inclusive conservation policies (*e.g.*, Global Biodiversity Framework, CBD, 2022) and contributes to advancing

knowledge and monitoring for aquatic ecosystem management, aligning with the implementation of Sustainable Development Goal 14.A (Jarić *et al.*, 2020). Compared with traditional surveys, user-generated geolocated imagery offers broader temporal and spatial perspectives on socio-ecological interactions (Wang *et al.*, 2018; Ghermandi *et al.*, 2023) that earlier studies could not capture (Alberti *et al.*, 2024). This method provides advantages such as large sample sizes, spatially explicit and low-cost data collection, and complementarity with conventional methodologies (Huang *et al.*, 2013; Thiagarajah *et al.*, 2015). Nonetheless, limitations include changing platform popularity, restricted access, user biases, and the emotional nature of online content (Ghermandi *et al.*, 2023; Wang *et al.*, 2018). Importantly, social media enables simultaneous data collection from diverse social actors, capturing multiple human–nature relationships (Gómez-Baggethun and Barton, 2013) and helping address issues of resource inequity in sustainability science (Wu, 2013). Although still limited in South America, studies using social media to explore people's valuation of natural environments are increasing (Martínez Pastur *et al.*, 2016; Walden-Schreiner *et al.*, 2018; Rossi *et al.*, 2020; Martínez-Harms *et al.*, 2018), to which this research contributes by reinforcing the view of environmental issues as socio-ecological systems.

5 Conclusions

This study represents the first sociocultural valuation of nature in northwestern Argentina using user-generated social media data, contributing to the limited body of research conducted in South America and Argentina. Rivers and waterfalls were the most photographed ecosystems, with a notable concentration in the mountainous areas of the Yungas, reflecting a diversity of values, uses, and activities, predominantly recreational, despite being less accessible than rivers in

central-eastern portion of the province where negative values were recorded for Foothill Forest and plain rivers, generally located near cities and roads.

These findings highlight the importance of adopting more participatory methodologies that integrate multiple knowledge systems and values into environmental planning and management to ensure ecosystem conservation. Furthermore, this type of methodology can serve as a facilitator of cultural heritage, providing novel and valuable information on people-nature relationships and socio-environmental conflicts that might otherwise remain undetected using traditional approaches.

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Supplementary material

Supplementary Material S1. URLs of Google Maps and YouTube images.

The Supplementary Material is available at <https://www.kmae-journal.org/10.1051/kmae/2025028/olm>.

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