

# Ecological condition of the riverbanks of the Cacaluta river, Chiapas, México

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## ABSTRACT

**Objective** To evaluate the bank quality of the river Cacaluta, Chiapas, Mexico, using a structural and functional approach applying the RQI index.

**Design/methodology/approach:** Twenty-six sites were evaluated based on their characteristics and location in the watershed. Surveys were performed using line transects between 180 and 550 m, and approximately 2-3 km apart. Overall.

**Results:** show a river with important degradation signs, three sites show good quality, while twenty-two sites show moderate quality, ten sites show poor quality, and one site has bad quality. The most affected attributes were width of the riverbank, longitudinal continuity, vegetation structure and composition, and vegetation diversity and regeneration. The study sites far from rural areas and of difficult access show better quality and conserved riverbank. The presence of human settlements, livestock, agriculture, and river canalization and dredging are the influential activities that result in poor quality sites.

**Limitations on study/implications:** No limitations were identified; however, further evaluations are needed.

**Findings/conclusions:** the development model implemented in the Cacaluta river basin does not represent any guarantee of sustainability for ecological functioning of the river, since the change and use of land adjacent to the riverbanks and the uncontrolled population growth implies significant pressure on riverbanks.

**Keywords:** fluvial system, riparian forest, watershed

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## INTRODUCTION

The natural value of riverbanks goes beyond physiognomic and taxonomic aspects, as they are considered important elements of landscape diversification and, above all, as biological and stabilizing components of fluvial ecosystems (Jimeno *et al.*, 2025; Corenblit *et al.*, 2015; Suárez and Vidal-Abarca, 2000).

Riparian vegetation in good condition provides multiple environmental services to fluvial landscapes, including bank stabilization, generation of aquatic and terrestrial habitats, nutrient filtering, CO<sub>2</sub> sinks, entry of food sources into the channel, regulation

of water temperature and luminosity, acting as a barrier to flood waters and generation of ecological corridors (Corenblit *et al.*, 2024; Ortiz, 2019; Palma *et al.*, 2009; Rico *et al.*, 2006).

However, riparian areas are not immune to anthropic pressure on rivers, where changes in land use for agricultural and livestock areas, channeling of the stretches on which they are located, construction of hydraulic infrastructure, and pollution by invasive species have affected their structure and functioning and, consequently, a reduction in the environmental services they provide at local and global levels (Ortiz *et al.*, 2024; Riis *et al.*, 2020; Millennium Ecosystem Assessment, 2005; Cecon, 2003). Therefore, the environmental assessment of riverbanks is nowadays a topic of great interest, and methods have been developed for a rapid and effective evaluation of the ecological state of riverbanks (Escalona-Domenech *et al.*, 2021; Feio *et al.*, 2021; González del Tánago and García de Jalón, 2006). There are several methods to estimate the quality of riparian vegetation and evaluation of the ecological state of riverbanks, such as the river habitat index (IHF) (Pardo *et al.*, 2002), the riparian forest quality index (QBR) (Munné *et al.*, 2003), Riparian Quality Index (RQI) (González del Tánago and García de Jalón, 2011), Riparian Forest Evaluation (RVF) (Magdaleno *et al.*, 2010), among others.

The RQI index collects quantitative information by evaluating seven attributes related to the structure and functioning of riparian systems, which are strongly determined by hydromorphological river dynamics (González del Tánago and García de Jalón, 2006). With the information generated by applying the RQI index, elements are provided allowing the competent authorities, civil organizations or the public to build integrated riparian vegetation management plans or schemes, which in some countries are nonexistent (Ortiz, 2019; Rodríguez-Téllez *et al.*, 2012; González del Tánago and García de Jalón, 2011).

Given its location, the Cacaluta River is of high ecological importance (CONAGUA, 2011), where the geomorphology of the area and the plant formations found in the watershed provide a high ecosystemic diversity, which is why this basin is part of the polygons of two natural protected areas (NPAs): El Triunfo Biosphere Reserve (REBITRI) and La Encrucijada Biosphere Reserve (REBIEN) with RAMSAR category (The Nature Conservancy, 2010). However, this river exhibits a significant alteration in its ecological functioning due to agricultural production practices, the conversion of natural ecosystems into productive areas and canalization works, as well as the lack of knowledge and interest shown by governments or agencies responsible for addressing this environmental situation (The Nature Conservancy, 2010; Tovilla, 2005). Therefore, the Cacaluta River, like most of the rivers of the Chiapas coast, is currently one of the most threatened ecosystems (Tovilla, 2005). The objective of this study was to evaluate the quality of the Cacaluta riverbank from a structural and functional point of view by applying the RQI index. The following hypotheses were proposed: 1) the ecological functioning of the Cacaluta River is expected to be better in areas where the riparian vegetation has not been altered than in areas where it has been, and 2) the banks of the Cacaluta River exhibit a good quality in areas within and adjacent to the natural protected areas in the upper and lower parts of the basin compared to those areas where land has been changed for use.

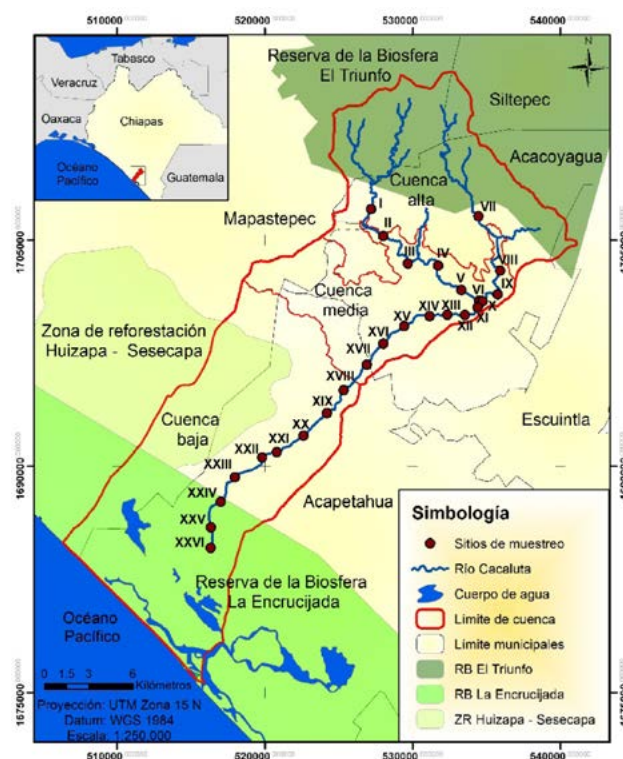
## MATERIALS AND METHODS

### Study area

The Cacaluta hydrological basin (where the river of the same name is located) belongs to hydrological region number 23: Chiapas coast. It is in the eastern part of the Sierra Madre de Chiapas and the Pacific Coastal Plain, within the coordinates 15° 32' 24" and 15° 10' 36" north latitude and 92° 56' 24" and 92° 37' 36" west longitude, with a surface area of 462.24 km<sup>2</sup> (CONAGUA, 2010) (Figure 1).

The Cacaluta River flows 51 km, with an average flow of 144.2 m<sup>3</sup>/s. From its river source in El Triunfo Biosphere Reserve (at an altitude of 2436 m.a.s.l.), it flows southwest into the wetlands of La Encrucijada Biosphere Reserve. The predominant climate in the basin according to Köppen's classification is warm humid with abundant rainfall in summer (Am(w)). The average annual rainfall is 2,911 mm with an average rainfall of 3,600 mm in the rainiest years for the period from May to October with an average temperature of 27 °C (CONAGUA, 2010).

The basin is located mainly in socioeconomic regions IX Istmo-Costa and X Soconusco, covering part of the territories of five municipalities: Acacoyagua, Acapetahua, Escuintla, Mapastepec and Siltepec, with a total of 214 localities scattered along the Cacaluta River. In total, the population density along the river is estimated to be 16,043 inhabitants according to the Population and Housing Census (INEGI, 2020). The Cacaluta river basin has remnants of mesophilic forest in the upper part along with medium sub evergreen forest that is distributed to the middle part and the presence of



**Figure 1.** Cacaluta river watershed, Chiapas. The twenty-six study sites are shown in red circles.

hydrophilic vegetation in the lower part, where the red mangrove (*Rhizophora mangle*) is the dominant species (Vásquez, 2008). In terms of land use, the watershed has a variety of crops such as African palm, mango, coffee, banana, seasonal agriculture, livestock, among others. Grasslands represent the largest extension in the basin with an area of 14131.76 ha.

### **Selection of sampling sites**

In choosing the number of sampling sites, the length of the river under study and the desired detail were considered, provided that the distance between sampling sites did not exceed 10 km, since at greater distances the aspects described would not have continuity and the resulting values would be very varied and a large part of the existing riparian vegetation would remain unevaluated (Rodríguez-Téllez *et al.*, 2012; Acosta *et al.*, 2009). As a result, 26 sampling sites were selected at an approximate equidistance of two to three kilometers, with accessibility to the sites being very important. Therefore, site VII was taken as the reference site for the REBITRI area (Figure 1). The study section was determined according to the riverbank width plus the sum of 20 m of contiguous width to the riverbed (10 m on each side) in accordance with Article 3, section XLVII of the National Water Act. The sum of both values was multiplied by five according to the Mexican standard for ecological flow in hydrological watersheds, NMX-AA-159-SCF1-2012 (SE, 2012), thus obtaining the length of the study section, which was divided in two to determine the distance to be traveled both upstream and downstream.

### **Application of RQI index**

To evaluate the ecological quality of the riverbank, the RQI index (González del Tánago and García de Jalón, 2011) was used, which integrates attributes related to the riverbank structure and functioning. The structure is characterized by the longitudinal continuity of vegetation, lateral dimensions (width) of river space containing natural riparian vegetation and composition and structure of riparian plant communities. Riparian forest functioning is reflected through the natural regeneration rate of riparian woody species, the condition of the banks, the lateral connectivity of the channel with its banks and the permeability of riparian soils.

These seven attributes were applied to the study sections (distance ranged from 180 to 550 m) throughout February and March 2014. Each of the attributes was evaluated on a scale of 1 to 15, according to its frame of reference, where the higher the score, the better the ecological condition of the riverbanks. Attributes related to riverbank structure were evaluated separately for each riverbank while attributes related to riverbank functioning were evaluated together for both banks. Each attribute was evaluated on a quality scale from 1 to 15, being very good (15-13), good (12-10), moderate (9-7), poor (6-4) and bad (3-1). Upon completion, the value of each attribute was added to determine overall assessment of riverbank quality of study section based on index ranges: very good (150-130), good (129-100), moderate (99-70), poor (69-40), bad (39-10) and very bad (<10) (González del Tánago and García de Jalón, 2011).

## RESULTS

Four of the six quality ranges for the RQI index were found in the 26 sampled sites. Stations V, VII, and VIII exhibited good bank condition (103-121 points), while site XVII exhibited a poor bank condition (39 points), mainly due to the presence of human settlements, a gabion structure for flood control, the removal of riparian vegetation to introduce crops such as oil palm, and the silting of the riverbed due to the lack of communication between the river and its floodplain (Figure 2). The other two quality ranges present were moderate and poor, the former being the one with the highest presence with 12 sites (Table 1 and Figure 3).

Regarding the attributes of the riverbank structure, the bank width exhibited significant alterations due to the change and use of adjacent land, with values ranging from 4 to 7 points mainly, with only sites V, VII and VIII showing a bank width in good condition (10-12) (Table 1). The longitudinal continuity showed a fragmentation by human actions, compromising its function as a corridor, since most of the sites exhibited a poor to moderate quality (4 to 8 points) while the composition and structure is composed by the dispersion of trees of the native or original vegetation such as *Sideroxylon portoricense* Urb., *Dendropanax arboreus* (L.) Decne. & Planch., *Calophyllum brasiliense* Cambess., *Vatairea lundellii* (Standl.) Killip ex Record, *Plumeria rubra* L., *Aspidosperma megalocarpon* Müll. Arg., among others, with an abundance in open spaces of shrub and herbaceous species with riparian preferences such as *Euphorbia graminea* Jacq., *Acalypha macrostachya* Jacq., *Boehmeria ulmifolia* Wedd., *Amaranthus spinosus* L., *Indigofera suffruticosa* Mill., *Costus pulverulentus* C. Presl, *Casearia sylvestris* Sw and *Panicum maximum* Jacq. In terms of attributes related to functioning, age and regeneration diversity of sites I, V, VII and VII exhibited all age classes (seedlings, juveniles and adults) of the main woody species mentioned above, while sites XVI to XXVI exhibited poor quality (4 to 6 points) due to channelization of the river, preventing the natural regeneration of woody species such as *Coccoloba barbadensis* Jacq., *Tabebuia rosea* (Bertol.) A. DC., *Bursera simaruba* (L.) Sarg., *Diphysa americana* (Mill.) M. Sousa, *Ficus obtusifolia* Kunth, *Platymiscium dimorphandrum* Donn. Sm., *Swietenia humilis* L., to name a few.

The condition of banks in most sites from I to XIII (except for VII) exhibited good quality (10-12) with dead wood and vegetal detritus on the sides of the riverbed, while the



**Figure 2.** From left to right: diversion of water with a barrier of sandbags, silted channel, laminar flow over a sandy bed surrounded by oil palm crops and effects of river channeling in the lower reaches. Photographs taken in the field by the author Jorge Hernández Hernández.

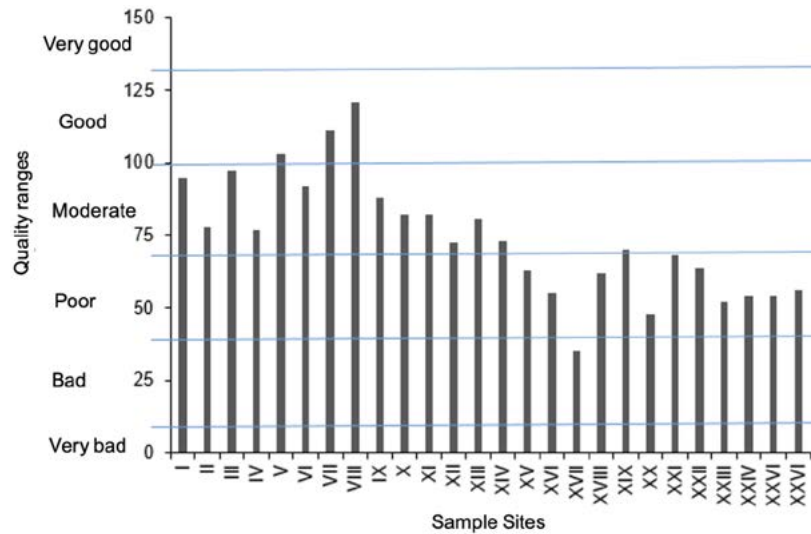
**Tabla 1.** Value for each attribute of the RQI index for the sampling sites of the Cacaluta river, Chiapas.

Sites	Attributes							Total	Basin	ANP
	AER*	CLV*	CEV*	RN	CO	CLC	PS			
I	15 (8.7)	15 (8.7)	16 (9.7)	11	12	13	13	95	High	No
II	12 (7.5)	13 (7.6)	13 (7.6)	7	10	11	12	78	Medium	No
III	15 (6.9)	19 (8.11)	20 (7.13)	9	11	12	11	97	Medium	No
IV	10 (5.5)	13 (6.7)	13 (6.7)	6	10	13	12	77	Medium	No
V	19 (13.6)	20 (13.7)	20 (13.7)	10	10	13	11	103	Medium	No
VI	13 (10.3)	16 (11.5)	17 (12.5)	8	11	15	12	91	Medium	No
VII	21 (8.13)	22 (9.13)	21(8.3)	10	11	13	13	111	High	Yes
VIII	23 (11.12)	24 (12.12)	24 (12.12)	12	12	13	12	120	Medium	No
IX	16 (8.8)	16 (8.8)	14 (7.7)	8	10	12	12	88	Medium	No
X	13 (7.6)	14 (7.7)	14 (7.7)	7	7	15	12	82	Medium	No
XI	12 (6.6)	12 (6.6)	12 (6.6)	5	13	15	13	82	Medium	No
XII	15 (7.8)	15 (7.8)	13 (6.7)	7	10	11	11	72	Medium	No
XIII	12 (6.6)	14 (7.7)	14 (7.7)	8	11	11	11	81	Medium	No
XIV	10 (5.5)	11 (6.5)	12 (7.5)	8	7	6	9	73	Medium	No
XV	8 (4.4)	15 (8.7)	10 (5.5)	8	7	6	9	63	Medium	No
XVI	8 (5.3)	11 (7.4)	8 (5.3)	4	8	6	10	55	Medium	No
XVII	7 (4.3)	6 (3.3)	6 (3.3)	3	3	4	7	36	Medium	No
XVIII	7 (4.3)	9 (5.4)	11 (5.6)	5	9	11	10	62	Low	No
XIX	13 (6.7)	13 (6.7)	12 (6.6)	8	9	5	10	70	Low	No
XX	9 (4.5)	8 (4.4)	8 (4.4)	3	7	8	5	48	Low	No
XXI	9 (3.9)	14 (6.8)	11 (4.7)	6	9	9	10	68	Low	No
XXII	8 (5.3)	12 (7.5)	12 (6.6)	6	9	8	9	64	Low	No
XXIII	9 (6.3)	9 (6.3)	9 (6.3)	5	5	5	10	52	Low	No
XXIV	6 (3.3)	12 (6.6)	8 (4.4)	4	10	4	10	54	Low	Yes
XXV	11 (6.5)	10 (5.5)	10 (5.5)	4	7	5	7	54	Low	Yes
XXVI	9 (4.5)	11 (5.6)	9 (4.5)	4	5	10	8	56	Low	Yes

Note. \* Sum of the values of both margins; AER: Width of riparian space; CLV: longitudinal continuity of vegetation; CEV: composition and structure of riparian vegetation; RN: natural regeneration rate of riparian woody species; CO: condition of banks; CLC: lateral connectivity of the channel with its banks and PS: permeability of riparian soils; ANP: Location within Natural Protected Areas.

rest of the sites (XIV to XXVI) exhibited a moderate to poor quality (5 to 7 points). The lateral connectivity and flooding of sites I to XIII exhibited the best conditions allowing flooding to the alluvial plain while the rest of the sites were cataloged with a moderate to poor quality (5 to 7 points) (Table 1), because they exhibit a significant reduction in the magnitude and frequency of natural flooding due to the channelization of the riverbed, with only overflow occurring with large floods. In relation to the substrate and vertical connectivity, most sites have a good infiltration quality (10-12 points) because there are no paved areas or significant extraction of stone minerals (sand and gravel).

Based on the previous paragraphs, a significant alteration was observed in four of the seven attributes of the RQI index, namely width, longitudinal continuity, composition,

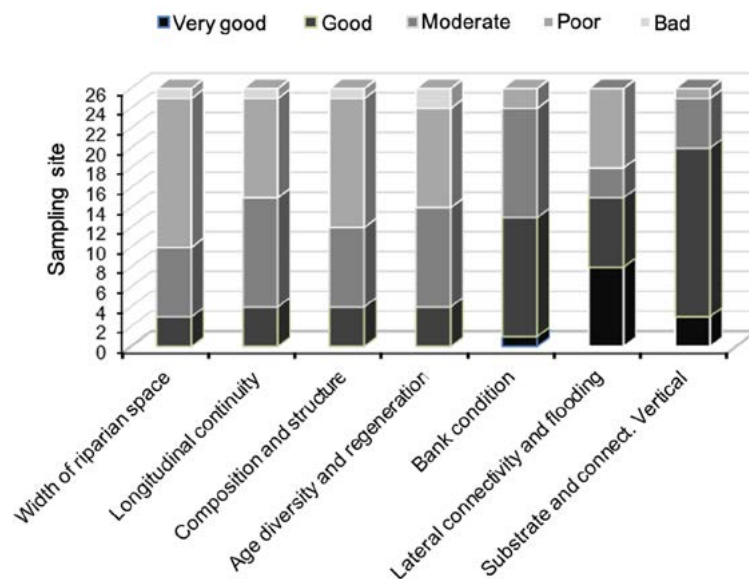


**Figure 3.** Histogram for RQI values obtained at each sampling site of the Cacaluta river.

structure, age and regeneration diversity of the riparian space. The range of quality for these attributes was from moderate to poor (Figure 4).

**DISCUSSION**

Site VII, located in the upper part of the basin and as a reference point for the REBITRI, had a good quality range (111 points), as did sites V (103 points) and VIII (121 points) located in the middle part of the basin, related to places difficult to access and areas far from population centers. As one begins to descend towards the mouth of the Cacaluta river, site quality begins to vary towards the moderate to poor ranges, like what is described by Suárez-Alonso and Vidal-Abarca (2000) for the Segura River in Spain; Fernández *et*



**Figure 4.** Quality stage of the studied attributes using the RQI index in the 26 study sites of the Cacaluta river.

*al.* (2009) for the Maullín river in Chile, Rodríguez-Téllez *et al.* (2016) for the La Sauceda river in México and Escalona-Domenech *et al.* (2021) for the Margarita river in Chiapas, México. With this statement, the hypothesis that the sites located within natural protected areas exhibit better riverbank quality with respect to the middle of the watershed where there has been a change in land use is partially fulfilled, since sites XXIV, XXV and XXVI located in the REBIEN exhibited poor riverbank quality, so it is ruled out that the presence of NPAs in the area are a conditioning factor for conserving riverbanks.

The most affected site was XVII with a poor quality due to its proximity to two population centers with the highest population, Hidalgo (1343 inhabitants) and Jiquilpan (1097 inhabitants), like what was reported by Kutschker *et al.* (2009) and Escalona-Domenech *et al.* (2021), where the areas rated with the worst quality corresponded to those closest to population centers. With respect to the hypothesis that the ecological functioning of the Cacaluta River is better in areas where the riparian vegetation has not been altered than in areas that were modified, this is completely fulfilled, since sites V, VII and VIII, which showed a range of good quality, consequently exhibited values of very good to good quality (10 to 13 points) in all attributes (see Table 1), as shown Mendoza-Cariño *et al.*, 2023.

Different degradation effects were observed in the Cacaluta riverbank due to some human activities such as deforestation, grazing, agriculture, dredging and canalization, these being the conditioning factors that determined the low scores in most of the sampling sites as reported by Diaz-Pascacio *et al.* (2018), Ortiz (2019); and Escalona-Domenech *et al.* (2021). The structure attributes of the sites located in the middle and lower reaches of the Cacaluta River exhibited a poor quality, which implies that the riverbank suffers from loss, fragmentation or replacement of natural vegetation and thus reduces the possibility of the riverbank acting as a biological corridor between the REBITRI and the REBIEN. The application of the RQI index to evaluate the structure and functioning of riparian vegetation gave a clear idea of the current conditions of this ecosystem, proving to be a simple tool that can be quickly applied and provides a great deal of hydromorphological information on river systems (González del Tánago *et al.*, 2006).

## CONCLUSIONS

Given the results obtained in this study, the development model implemented in the Cacaluta river basin does not represent any guarantee of sustainability for ecological functioning of the river, since the change and use of land adjacent to the riverbed and the uncontrolled population growth implies significant pressure on riverbanks. Even though in Mexico, Article 34 (section III) of the General Climate Change Act proposes that policies and actions must be designed and carried out to protect, conserve and restore riparian vegetation in the use, development and exploitation of riverbanks or federal zones, to date no action has been taken by competent agencies for the Cacaluta River. Therefore, it is essential to develop short- and medium-term management plans for riverbanks using restoration and rehabilitation measures and to reduce pressures and impacts as much as possible to ensure the ecological integrity of the Cacaluta River and at the same time ecological connectivity between the REBITRI and the REBIEN. Faced with this scenario,

there is an alternative to improve the Cacaluta riverbank situation in the medium term, given that CONAGUA (2011) states that this river has a medium feasibility for establishing a potential water reserve, through the detection of an ecological flow.

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## REFERENCES

- Acosta, R., Ríos, B., Rieradevall, M., & Prat, N. (2009). Propuesta de un protocolo de evaluación de la calidad ecológica de ríos andinos (CERA) y su aplicación a dos cuencas en Ecuador y Perú. *Limnetica*, 28(1), 35-64.
- Ceccon, E., (2003). Los bosques ribereños y la restauración y conservación de las cuencas hidrográficas. *Ciencias* 72, 46-53.
- Comisión Nacional del Agua CONAGUA. (2010). Construcción de obras de protección de los márgenes del río Cacaluta en los municipios de Acacoyagua y Acapetahua, Chiapas. Estudio de impacto ambiental.
- Comisión Nacional del Agua CONAGUA. (2011). Identificación de reservas potenciales de agua para el medio ambiente en México. Secretaría de Medio Ambiente y Recursos Naturales. Talpan, México. <https://www.conagua.gob.mx/conagua07/publicaciones/publicaciones/sgt-3-11media.pdf>
- Corenblit, D., Davies, N. S., Steiger, J., Gibling, M. R., & Bornette, G. (2015). Considering river structure and stability in the light of evolution: feedbacks between riparian vegetation and hydrogeomorphology. *Earth Surface Processes and Landforms*, 40(2), 189-207. <https://doi.org/10.1002/esp.3643>
- Corenblit, D., Piégay, H., Arrignon, F., González-Sargas, E., Bonis, A., Ebengo, D. M., ... & Walcker, R. (2024). Interactions between vegetation and river morphodynamics. Part II: Why is a functional trait framework important? *Earth-Science Reviews*, 104709. <https://doi.org/10.1016/j.earscirev.2024.104709>
- Díaz-Pascacio, E., Ortega-Argueta, A., Castillo-Uzcanga, M. M. and Ramírez-Marcial, N. (2018). Influence of land use on the riparian zone condition along an urban-rural gradient on the Sabinal River, Mexico. *Botanical Sciences*, 96, 180-199. <https://doi.org/10.17129/botsci.1858>
- Escalona-Domenech, R., Infante-Mata, D., García-Alfaro, J. R., Ramírez-Marcial, N., Oryiz-Arrona, C. N., & Barba-Macías, E. (2021). Calidad de las riberas en tres tipos de cobertura vegetal en un río de la Sierra Madre de Chiapas, México. *Revista Mexicana de Biodiversidad*, 92(4), e923526. <https://doi.org/10.22201/ib.20078706e.2021.92.3526>
- Feio, M. J., Hughes, R. M., Callisto, M., Nichols, S. J., Odume, O. N., Quintella, B. R., ... & Yates, A. G. (2021). The biological assessment and rehabilitation of the world's rivers: An overview. *Water*, 13(3), 371. <https://doi.org/10.3390/w13030371>
- Fernández, L., Rau, J., & Arriagada, A. (2009). Calidad de la vegetación ribereña del río Maullín (41° 28' S; 72° 59' O) utilizando el índice QBR. *Gayana. Botánica*, 66(2), 269-278. <http://dx.doi.org/10.4067/S0717-66432009000200011>
- González del Tánago, M., & García de Jalón, D. (2006). Attributes for assessing the environmental quality of riparian zones. *Limnetica*, 25(1-2), 389-402. <https://doi.org/10.23818/limn.25.27>
- González del Tánago, M., & García de Jalón, D. (2011). Riparian Quality Index (RQI): A methodology for characterising and assessing the environmental conditions of riparian zones. *Limnetica*, 30(2), 0235-254. <https://doi.org/10.23818/limn.30.18>
- Instituto Nacional de Estadística y Geografía (INEGI), 2020. Censo de población y vivienda. D.F., México.
- Jimeno, D., Chávez, D., Enríquez, M., Fonseca, R. M., Gallardo-Cruz, J. A., Martínez-Camilo, R., & Meave, J. A. (2025). Floristic and Structural Heterogeneity in a Neotropical Riparian Wetland: Conservation Implications. *Wetlands*, 45(1), 17 <https://doi.org/10.1007/s13157-025-01902-2>
- Kutschker, A., Brand, C., & Miserendino, M. L. (2009). Evaluación de la calidad de los bosques de ribera en ríos del NO del Chubut sometidos a distintos usos de la tierra. *Ecología austral*, 19(1), 19-34.
- Magdaleno, F., Martínez, R., & Roch, V. (2010). Índice RFV para la valoración del estado del bosque de ribera. *Ingeniería civil*, 157, 85-96.
- Mendoza-Cariño, M., Cruz-Flores, G., & Mendoza, D. (2023). Salud de los bosques de galería y de los ecosistemas ribereños. *Madera y Bosques*, 29(1), 1-15. <https://doi.org/10.21829/myb.2023.2912387>

- Millennium Ecosystem Assessment, (2005). Ecosystems and human well-being: Wetlands and water (synthesis). World Resources Institute, Washington, DC.
- Munné, A., Prat, N., Solà, C., Bonada, N., & Rieradevall, M. J. A. C. M. (2003). A simple field method for assessing the ecological quality of riparian habitat in rivers and streams: QBR index. *Aquatic conservation: marine and freshwater ecosystems*, 13(2), 147-163. <https://doi.org/10.1002/aqc.529>
- Ortiz, C. I. (2019). Los corredores ribereños en la cuenca del río Ayuquila-Armería en México. Vegetación ribereña y calidad de las riberas. Universidad de Guadalajara, Centro Universitario de la Costa Sur.
- Ortiz, C., Jofré, M., & González, P. (2024). Diagnóstico integral de un río urbano. Aplicación de métricas biológicas, fisicoquímicas y del bosque de ribera. *Ecosistemas*, 33(1), 2613-2613. <https://doi.org/10.7818/ECOS.2613>
- Palma, A., Figueroa, R., & Ruiz, V. H. (2009). Evaluación de ribera y hábitat fluvial a través de los índices QBR e IHF. *Gayana (Concepción)*, 73(1), 57-63. <http://dx.doi.org/10.4067/S0717-65382009000100009>
- Pardo, I., Álvarez, M., Casas, J., Moreno, J. L., Vivas, S., Bonada, N., ... & Vidal-Abarca, M. R. (2002). El hábitat de los ríos mediterráneos. Diseño de un índice de diversidad de hábitat. *Limnetica*, 21(3-4), 115-133. <https://www.limnetica.com/documentos/limnetica/limnetica-21-2-p-115.pdf>
- Rico, F. C., Trejo, I., & Bonfil, C. (2006). Estructura y composición de la vegetación ribereña de la barranca del río Tembembe, Morelos, México. *Boletín de la Sociedad Botánica de México*, (78), 17-31.
- Riis, T., Kelly-Quinn, M., Aguiar, F. C., Manolaki, P., Bruno, D., Bejarano, M. D., ... & Dufour, S. (2020). Global overview of ecosystem services provided by riparian vegetation. *BioScience*, 70(6), 501-514. <https://doi.org/10.1093/biosci/biaa041>
- Rodríguez-Téllez, E., Domínguez-Calleros, P. A., Pompa-García, M., Quiroz-Arratia, J. A., & Pérez López, M. E. (2012). Calidad del bosque de ribera del río El Tunal, Durango, México; mediante la aplicación del índice QBR. *Gayana. Botánica*, 69(1), 147-151. <http://dx.doi.org/10.4067/S0717-66432012000100014>
- Rodríguez-Téllez, E., García-De-Jalón, D., Pérez-López, M. E., Torres-Herrera, S. I., Ortiz-Carrasco, R., Pompa-García, M., ... & Vázquez Vázquez, L. (2016). Caracterización de la calidad ecológica del bosque de galería del río La Saucedá, Durango, México. *Hidrobiológica*, 26(1), 35-40. <https://doi.org/10.24275/uam/izt/dcbs/hidro/2016v26n1/Rodriguez>
- Secretaría de Economía SE. (2012). Norma Mexicana NMX-AA-159-SCFI-2012. Establece el procedimiento para la determinación del caudal ecológico en cuencas hidrológicas. Secretaría de Economía. 20 de septiembre del 2012, Diario Oficial de la Federación. Cd. Mx., México. <https://www.gob.mx/cms/uploads/attachment/file/166834/NMX-AA-159-SCFI-2012.pdf>
- Suárez-Alonso, M. L. and Vidal-Abarca, G. (2000). Aplicación del índice del bosque de ribera, QBR (Munné *et al.*, 1998) a los cauces fluviales de la cuenca del río Segura. *Tecnología del Agua*, 33-45.
- The Nature Conservancy. (2010). Perspectiva general de asuntos relacionados con el manejo de las cuencas costeras de Chiapas. Informe de visita técnica. TNC, USAID, Forest Service Department of Agriculture. Chiapas, México.
- Tovilla, C. H. (2005). Agonía y desaparición de los ríos y humedales en la costa de Chiapas. *Ecofronteras*, 5-8. <https://revistas.ecosur.mx/ecofronteras/index.php/eco/article/view/873>
- Vásquez, S. M. (2008). Zonas afectadas por el huracán Stan en las regiones Istmo-Costa, Sierra y Soconusco. CONACYT-Cocytech. Chiapas. México. <https://biblioteca.ecosur.mx/cgi-bin/koha/opac-retrieve-file.pl?id=ec197e04cf6a72c62ea582c27aa28573>