water

MDPI

Article

Changes in Surface Water Quality of the El Salvador River in La Joya de los Sachas, Ecuadorian Amazon Region

Tannia Vargas-Tierras [1], Mirian Jiménez-Gutiérrez [2], Sandra Pastrano [3], Gino Chávez [3], Vanessa Morales-León [4], María Morales-León [3], Fernando Paredes [5] and Wilson Vásquez-Castillo [6,*]

1 Research Group YASUNI-SDC, Sede Orellana, Escuela Superior Politécnica de Chimborazo (ESPOCH), El Coca 220001, Ecuador; tannia.vargas@espoch.edu.ec
2 Sede Orellana, Escuela Superior Politécnica de Chimborazo (ESPOCH), El Coca 220001, Ecuador; mirian.jimenez@espoch.edu.ec
3 Independent Researcher, El Coca 220001, Ecuador; sandra.pastrano200@hotmail.com (S.P.); k_g_j@hotmail.es (G.C.); maria.agustamorales@gmail.com (M.M.-L.)
4 Facultad de Recursos Naturales, Escuela Superior Politécnica de Chimborazo, Panamericana sur km 1 ½, Riobamba 060106, Ecuador; vanessa.moralesl@espoch.edu.ec
5 Central Amazon Research Site (EECA), National Institute of Agricultural Research (INIAP), La Joya de los Sachas 220350, Ecuador; fjparedes.a@hotmail.com
6 Bio-Chemoinformatics Group, Ingeniería Agroindustrial, Universidad de Las Américas (UDLA), Redondel del Ciclista, Vía a Nayón, Quito 170124, Ecuador
* Correspondence: wilson.vasquez@udla.edu.ec; Tel.: +593-984-659-247

Abstract: Water effluent pollution in the Ecuadorian Amazon occurs mainly due to the lack of sewage infrastructure, wastewater treatment plants in urban and rural areas, and agricultural and livestock activities. Consequently, understanding water quality is crucial because of its dynamic nature, influenced by various activities along its course. We evaluated and compared the water quality status of the El Salvador River with the current standards of the Ministry of the Environment, Water, and Ecological Transition in Ecuador and with Decree No. 115/2003 on water quality and water pollution management. The water quality index was determined through random sampling at seven locations along the river. The results show good water quality, with contamination indices ranging from 84 to 87. When comparing the results with the standards, all water quality parameters met the standards for recreational purposes. However, considering the river's uses for agricultural activities, we compared the water with additional standards from legislation outlined by the Environment Ministry and found that the nitrate content exceeded permissible limits due to runoff from the surrounding crops, causing a potential risk to human health. Therefore, incorporating helophyte plants is a promising option that would promote the health of this aquatic ecosystem and others.

Keywords: contamination; physicochemical and biological parameters; regulations

Citation: Vargas-Tierras, T.; Jiménez-Gutiérrez, M.; Pastrano, S.; Chávez, G.; Morales-León, V.; Morales-León, M.; Paredes, F.; Vásquez-Castillo, W. Changes in Surface Water Quality of the El Salvador River in La Joya de los Sachas, Ecuadorian Amazon Region. *Water* **2024**, *16*, 1259. https://doi.org/10.3390/w16091259

Academic Editors: Fuhong Sun and Fanhao Song

Received: 11 March 2024
Revised: 18 April 2024
Accepted: 22 April 2024
Published: 28 April 2024

1. Introduction

Water quality is important for the preservation of ecosystems, health, agriculture, and industry [1], playing a fundamental role in the preservation of the environment as well as in the protection of human health [2]. However, the contamination of water sources is generally diffuse, i.e., it does not have a specific point of origin or is generated in large areas where its control and detection are complicated [3]. Agricultural activities, agricultural industrial discharges, and sewage systems are the main causes of a loss of surface water quality due to nutrient pollution [4,5]. To this, we must add natural factors, such as precipitation (intensity, frequency, and quantity), vegetation type, landscape, topography, soil type, and river flow, which add complexity to water quality management [2].

Several studies demonstrate the relationship between water quality and land use [6]. Settlement areas and the inadequate use of soil were found to be responsible for water degradation. The excessive use of fertilizers on cropland is one of the main causes of elevated nitrogen and phosphorus levels in water [6]. This is mainly because global nitrogen consumption accounts for 80% of anthropogenic nitrogen fixation [7]. In contrast, forested land and grassland correlate positively with water quality [8,9].

For this reason, monitoring emerges as a fundamental activity for the proper management of water resources. The early detection of worrying trends in water quality is the only way to identify the adverse effects of pollution and apply corrective and preventive measures [10]. Source water monitoring should become one of the main strategies [11]. One tool to assess water quality [12] is the Water Quality Index (WQI), based on a combination of physical, chemical, and biological factors, which are condensed into a single value ranging from 0 to 100 [13–16]. Its development involves four main processes: the selection of relevant parameters, normalization of the data to a uniform scale, assignment of weights, and aggregation of sub-indices [12,13]. The final value obtained is given a rating from excellent (91–100) to good (71–90), average (51–70), bad (26–50), or very bad (0–25) [13,17].

Given this situation, and knowing that the Ecuadorian Amazon Region faces this problem of water effluent contamination, mainly due to an absence of wastewater treatment plants in urban and rural areas, agricultural activities, and a lack of sewage infrastructure [18], the need arises to evaluate the water quality of the El Salvador River, located in Tres de Noviembre parish, La Joya de los Sachas canton. This is because, according to the Plan of Development and Territorial Planning of the Decentralized Autonomous Government (PDOT) of the Tres de Noviembre rural parish, the water in this river is used for agricultural and recreational purposes [19]. In the locality, families use 28% of the land for perennial crops (*Theobroma cacao* L., *Coffe canephora*, and *Elaeis guineensis*) and transitory crops (*Zea mays*, *Arachis hypogaea*, *Oriza sativa*, *Colocasia esculenta*, and *Musa* spp.), 29% for cultivated and natural pastures (especially for cattle raising), 4% for swampy soils, 25% for stubble, and 14% for forest.

On the other hand, the accelerated population growth of the La Joya de los Sachas canton due to oil intervention has awakened interest among tourists who want to explore the canton's flora, fauna, geography, and territory. In view of this situation, local authorities have identified some tourist attractions that promote economic activity in the sector. In the Tres de Noviembre parish, there are twenty-nine tourist attractions with ecological tourism, agro-tourism, adventure tourism, and cultural tourism activities [19]. Yet, it is in the El Salvador River, with a flow of 30.33 m^3/s, where the most important tourist attractions are located. This situation and anthropogenic activities in areas adjacent to the river have caused significant changes in water quality. For example, the water quality of several effluents that flow into the Jivino Rojo River was assessed by monitoring benthic macroinvertebrates (BMWP). Up until 2018, the water quality was good or acceptable, with a BMWP of 137 to 80, but from 2019, the BMWP index decreased to 51, an unacceptable level [20]. This change in water quality is very worrisome because in the Tres de Noviembre parish, 45% of the people use average-quality water and 9% use water of poor quality, especially because they use piped water (untreated), water from ponds and estuaries, and rainwater. In addition, 46% of the population uses treated water (good quality) from drilled wells. It is important to mention that the wastewater treatment plant has not been operating in the town since 2007. A total of 79% of households dispose of their excreta in septic tanks and 21% in the open air [21].

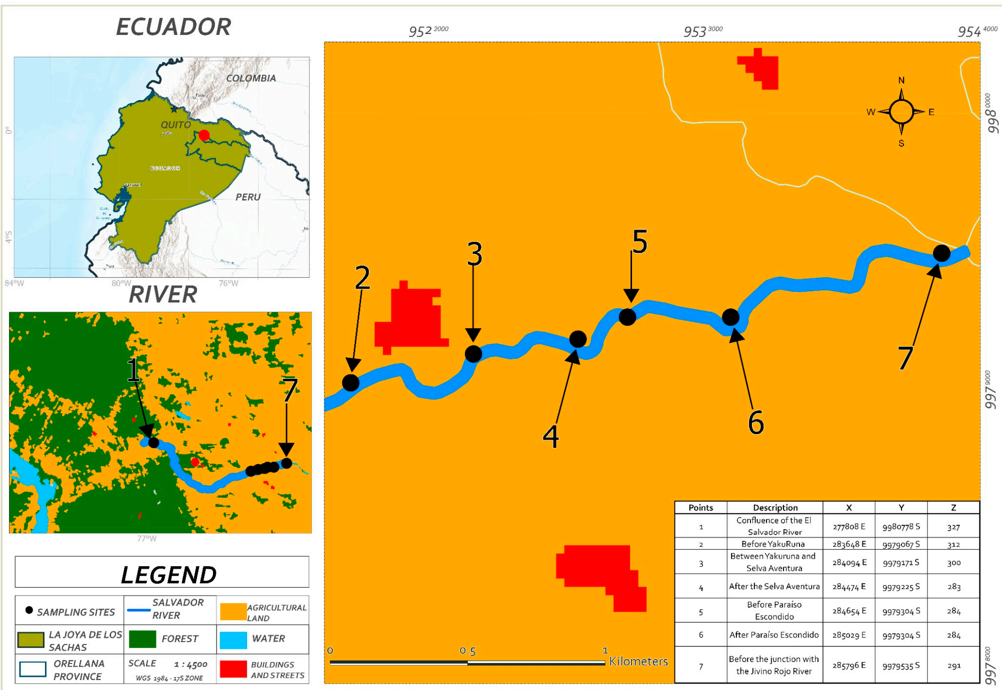
Subsequently, after finding that there were no water quality studies of the El Salvador River, a study was proposed to assess the water quality since this effluent flows through the three most important tourist centers in the sector, Yakuruna, Selva Aventura, and Paraíso Escondido, and because several agricultural and livestock activities are carried out along the river. For this analysis, the current standards of the Ministry of the Environment, Water, and Ecological Transition in Ecuador were reviewed [22] along with Decree No. 115/2003 on water quality and water pollution management and class III for fishing and animal husbandry [23]. The water quality index (WQI) was also calculated [13]. The findings of this research are intended to broaden our understanding of the connection between recreational activities and land use with surface water quality, which, in turn, will favor informed decision-making in the implementation of strategies to counteract or prevent the effects of pollution in the water body.

2. Materials and Methods

2.1. Study Area and Site Selection

The El Salvador River is located in the Tres de Noviembre parish, La Joya de los Sachas canton, Orellana Province. This parish is located in the micro-basin of the Jivino Rojo River (57.5%) and the Eno River (42.5%). It has a humid tropical climate with an average cloud cover of 5.5 oktas, average rainfall ranging from 2650 to 4500 mm per year, minimum temperature of 18 °C, maximum temperature of 42 °C, and average daily temperature of 25.6 °C [21].

A total of 7 sampling sites were selected on the El Salvador River. Sampling was carried out during the wettest months of the year, April, May, and June (306.1, 337.9, and 300.9 mm, respectively), every 15 days with two samplings per month for a total of 42 samples. The sampling sites were the following: Point 1—confluence of the El Salvador River with a minor tributary; Point 2—before the Yakuruna tourist center; Point 3—between Yakuruna and Selva Aventura; Point 4—after the Selva Aventura tourist center; Point 5—before Paraíso Escondido; Point 6—after Paraíso Escondido; and Point 7—at the end of the El Salvador River before the junction with the Jivino Rojo River (Figure 1). Site selection was based on in situ observations and the methodology proposed by Larrea et al. was followed [24], where the sampling points should be located in a place that presents a regular flow and, if possible, allows for a reference for future location. For the elaboration of the map, where the current land use surrounding the river was included, the national base map (scale 1:50,000) of the Military Geographic Institute of Ecuador was used [25] along with the Land Cover and Use Map (CUT 2022) of the Ministry of the Environment, Water, and Ecological Transition [26].



Points	Description	X	Y	Z
1	Confluence of the El Salvador River	277808 E	9980778 S	327
2	Before YakuRuna	283648 E	9979067 S	312
3	Between Yakuruna and Selva Aventura	284094 E	9979171 S	300
4	After the Selva Aventura	284474 E	9979225 S	283
5	Before Paraíso Escondido	284654 E	9979304 S	284
6	After Paraíso Escondido	285029 E	9979304 S	284
7	Before the junction with the Jivino Rojo River	285796 E	9979535 S	291

Figure 1. Study area where sampling was conducted in the El Salvador River. Sampling sites were georeferenced (x, y, z) and numbered from 1 to 7. Point 1: confluence of the El Salvador River with a minor tributary; Point 2: before the Yakurna tourist center; Point 3: between Yakuruna and Selva Aventura; Point 4: after the Selva Aventura tourist center; Point 5: before Paraíso Escondido; Point 6: after Paraíso Escondido; and Point 7: end of the El Salvador river before the junction with the Jivino Rojo River [25,26].

2.2. Data Collection

2.2.1. Physicochemical and Biological Analysis

At the study site, the water temperature and ambient temperature were recorded using a digital thermometer (ST9215, ATM Limited, Hong Kong, China). The containers used for sampling are the same as those detailed in the Ecuadorian Technical Standard (NTE-INEN 2169:2013) [27]. For turbidity, 100 mL plastic (P) and glass (G) containers were used; for biochemical oxygen demand, a 900 mL P and G container was used (test method 1202); for chemical oxygen demand, a 100 mL P and G container was used (test method 1203); for cadmium, nickel, and lead, a 100 mL P(A) and G(A) container was used (test method 1204 and 982); for nitrites and nitrates, a 100 mL P and G container was used (test method 1203); and for total coliforms and fecal coliforms, 100 mL P containers were used. Sample collection was carried out in three specific zones of the river section (left, right, and central) [28] according to the Water Technical Standard: Water Quality, Sampling, and Design of Sampling Programs (INEN 2226:2013) [29]. The analyses were carried out according to the methods suggested by Ann and Franson for the analysis of drinking water and wastewater (APHA-AWWA-WPCF) [30].

pH and electrical conductivity were measured in situ; pH, conductivity, dissolved oxygen (DO), and total dissolved solids were measured by electrometry according to standard methods 4500 H+B and 2510 B (HI 9829, HANNA, Carbon County, WY, USA). For turbidity determination, the standard method 2130 B was used with the nephelometry technique (HEDP167001, AquaMate Plus, Muscatine, IA, USA). Biochemical oxygen demand (BOD_5) was determined with the WTW OxiTop IS 12 (Oxitop, Madrid, Spain), using standard method 5210 B. Using spectrophotometry (HEDP167001, AquaMate Plus), nitrites and nitrates were determined, with nitrites according to method HACH 8507 and nitrates with method HACH 8192. Using flame spectrophotometry (C113500052, ICE 3500, Richmond Scientific, Lancashire, UK), cadmium, nickel, and lead were determined with standard methods 3030 B and 3111 B. The determination of fecal and total coliforms was carried out using standard method 9222 D by membrane filtration (AD-VANTEC Vacuum Filtration System, 353130 MANIFOLD3XVALVE, Suite A Dublin, CA, USA, and ESCO Incubator Oven, 87706, IFA-110-8, Singapore).

The flow velocity was determined with a current meter (range: 0.1 to 6.1 m s^{-1}) using the buoyancy method, considering a length of 5 m [30]. In addition, manual measurements of hydromorphological variables (depth and width of the river) were taken. The physicochemical and biological parameters selected for the El Salvador River were based on previous research carried out by Vargas-Tierras et al. [18,31].

2.2.2. Comparison with Water Quality Standards

The results of the analysis of the water quality variables of the El Salvador River, which are presented in Tables 1 and 2, were compared with the regulations of Reform Book VI of the Unified Text of Secondary Legislation of the Ecuadorian Environment Ministry—Ministerial Agreement 097-A (Supplementary S3). This book indicates the maximum limits allowed for water quality for human consumption (Supplemental Table 1), for the preservation of aquatic life and other wildlife (Supplemental Table 2), for irrigation (Supplemental Table 4), and for recreational purposes (Supplemental Table 6). The class III water quality standard for fish and livestock is stipulated in Government Regulation no. 82/2001, cited by Effendi in the study entitled Water quality status of Ciambulawung River, Banten Province, based on the pollution index and NSF-WQI in Supplementary Material S4 [23].

Table 1. Means, minimum (min), maximum (max), and standard deviation (SD) of the physicochemical and biological variables taken at the 7 sampling points along the El Salvador River.

Variable	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7
DO mean (mg L^{-1})	2.6	2.9	3.1	3.1	3	3.1	3
Min	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Max	4.3	5	5.3	5.4	5.4	5.1	5.1
SD	1.2	1.5	1.6	1.6	1.4	1.5	1.5
Confidence Interval	0.5–5.4	0.2–6.5	0.14–6.9	0.1–7.0	0.3–6.7	−0.4–7.24	0.2–6.5
Nitrates mean (NO_3) (mg L^{-1})	20.3	25.9	23.6	30.1	31.1	37.5	44.3
Min	15.3	15.3	16.6	15.2	20.9	20	16.2
Max	26.5	43.4	27.6	56.7	57	83.7	103.3
SD	4.6	12.3	4.8	18.6	17.2	30.9	40.7
Confidence Interval	10.8–31.1	3.3–55.4	11.8–32.4	−3.14–74.9	3.9–73.8	−22.6–143.2	−23.6–143.2
TDS mean (mg L^{-1})	94.5	93.8	94	87	94.7	95	95.4
Min	89.6	88.2	88.2	66.5	88.9	88.9	90.3
Max	98	98	97.3	96.6	98.7	98.7	98.7
SD	3.7	4.1	4	14.1	4.1	4.3	3.4
Confidence Interval	85.9–101.0	84.2–102	84.3–101	52.7–110	84.9–102	83.0–104	86.8–102
Total coliforms mean (col 100 mL^{-1})	155	112	141	133	138.5	138	148
Min	90	70	60	50	30	70	70
Max	218	188	238	240	240	200	230
SD	69.4	53.4	89.5	97.8	79.6	53.7	65.5
Confidence Interval	21.9–286.0	17.6–240.4	−27.7–325.7	−45.8–335.9	−48.1–318.1	−4.41–274.4	5.7–294.2
Fecal coliforms mean (col 100 mL^{-1})	30.5	20	27.8	18.8	47.8	41.5	39
Min	18	4	10	5	5	16	10
Max	60	34	44	30	120	90	66
SD	19.8	15.2	14.2	10.3	47.8	33.9	28.1
Confidence Interval	−1.4–79.4	−10.9–48.9	−3.91–57.9	−5.10–40.1	−45.0–170.0	−31.1–137.1	−17.6–93.6
pH mean	7.3	7.1	6.8	6.9	7.1	7.3	7.1
Min	6.5	6.5	6.2	5.9	6.7	7	6.6
Max	7.9	7.4	7.4	7.6	7.6	7.7	7.8
SD	0.6	0.4	0.5	0.8	0.4	0.4	0.5
Confidence Interval	5.8–8.5	6.1–7.8	5.8–7.9	5.1–8.4	6.3–8.1	6.4–8.2	6.1–8.2
Conductivity mean (µS cm^{-1})	134.5	134	134.3	124.3	135.25	135.3	136.3
Min	128	126	126	95	127	127	129
Max	138	139	139	138	141	141	141
SD	4.7	5.8	5.7	20.1	5.9	6.1	5.1
Confidence Interval	123.4–142.6	120.2–145.7	120.4–144.6	75.3–157.7	121.2–146.8	118.6–149.4	123.9–146.0
Flow velocity mean (m s^{-1})	0.5	0.3	10.8	8	0.7	0.5	0.6
Min	0.2	0.1	9	7	0.5	0.1	0.5
Max	0.7	0.6	12	9	12	0.8	0.6
SD	0.3	0.3	1.5	1.2	0.2	0.4	0.1
Confidence Interval	0.1–0.9	0.1–0.9	7.5–13.5	5.9–10.1	0.3–12.2	0.1–1.4	0.4–0.7
Depth mean (m)	0.6	0.7	1.6	0.7	1.7	0.8	0.8
Min	0.3	0.6	0.3	0.5	0.2	0.6	0.7
Max	0.9	0.8	2.2	0.8	3.2	1.2	0.9
SD	0.4	0.1	0.9	0.2	1.7	0.3	0.2
Confidence Interval	0.01–1.3	0.5–0.9	0.01–3.1	0.3–1.0	0.01–4.9	0.2–1.7	0.5–1.2
Water temperature mean (°C)	24.7	24.9	25	25.1	25.1	25.7	25.7
Min	24.5	24.7	24.7	24.8	24.9	25.1	25.1
Max	24.9	25.1	25.3	25.3	25.4	26.3	26.4
SD	0.3	0.3	0.4	0.3	0.3	0.9	0.9
Confidence Interval	24.2–25.1	24.3–25.4	24.3–25.7	24.5–26.0	24.6–26.0	23.9–28.0	24.3–27.2

Table 2. Water quality index at the seven sampling points along the El Salvador River.

Description	Units	Q Value							Subtotal Quality Index						
		1	**2**	**3**	**4**	**5**	**6**	**7**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
DO	mg L^{-1}	92.2	91.3	90.7	90.7	91.0	90.7	91.0	19.0	18.8	18.7	18.7	18.7	18.7	18.7
$N\text{-}NO_3$	mg L^{-1}	87.82	84.5	85.8	81.9	81.3	77.5	73.4	11.9	11.5	11.7	11.1	11.1	10.5	10.0
BOD_5	mgO_2 L^{-1}	100.0	100.0	100.0	100.0	100.0	100.0	100.0	13.6	13.6	13.6	13.6	13.6	13.6	13.6
TDS	mg L^{-1}	81.1	81.2	81.2	82.6	81.1	81.0	80.9	9.4	9.4	9.4	9.6	9.4	9.4	9.4
Fecal Coliforms	MPN 100 mL^{-1}	99.11	99.4	99.2	99.5	98.6	98.8	98.9	13.3	13.3	13.3	13.3	13.2	13.2	13.2
pH	-	53.5	54.5	56.0	55.0	54.5	53.5	54.5	8.3	8.5	8.7	8.6	8.5	8.3	8.5
Turbidity	NTU	100.0	100.0	100.0	95.5	92.7	92.3	88.3	11.6	11.6	11.6	11.1	10.8	10.7	10.2
Sum index									**87**	**87**	**87**	**86**	**85**	**85**	**84**
Average index												**86**			

2.2.3. Water Quality Index (WQI) Estimation

This tool is effective for the continuous assessment of water quality from various sources, which usually combines several parameters to describe the status of water resources and their suitability for various uses. Different authors have proposed varying weights for different water quality parameters [13,32].

$$\text{WQI} = \sum_{i=1}^{n} (SI_i \, * \, Wi) \tag{1}$$

where WQI: water quality index; subi: subscript the parameter *i*; and *wi*: relative weights or weight of importance for subscript *i*.

The value of QI was obtained from the function curves developed by Ott (1978) and Brown et al. (1970) for the parameters indicated, using the data collected during field measurements [33].

This value of QI was adjusted by multiplying it by the assigned weight (*wi*), as detailed in Supplemental Table 1. The sum of all these weights was matched with the water quality classification, which provides the water quality at each sampling point. It is important to note that when calculating the WQI of the El Salvador River, temperature variation was not considered in order to prevent this factor from distorting the results because the samples were taken at intervals of several hours and with alterations in cloud cover [34].

To ensure that the sum of the weights of all parameters is equal to unity, we relied on the document "Water Quality Indices (WQIs) and Contamination Indices (WQIs) of Global Importance" [13], which suggests that if any variable is missing, a correction factor should be applied to the total value of the index. This correction factor was calculated by distributing the missing weight among the other variables, and then the corresponding recalculation was performed (Table S1) [13,35]. In order to facilitate the interpretation of the information, instead of presenting a list of numerical values, this index is represented by colors. The relative weight of the parameters considered in the QWI and the color scale indicating water quality are shown below (Table S2) [13,36].

2.2.4. Data Analysis

Analyses were performed using R software version 4.1.1 developed by the R-Core Team in 2021 [37]. Prior to analysis, the data were normalized. A descriptive analysis of the physicochemical, biological, and hydromorphological variables was performed. The correlation between hydromorphological, biological, and physicochemical variables was examined using Spearman's coefficient.

3. Results

Physicochemical and Biological Analysis

The detailed results of the analysis are presented in Table 1. In this study, it was determined that the amount of dissolved oxygen and the presence of nitrates were lower in the first two sampling points (2.6 and 2.9; 20.3 and 25.9 mg L^{-1}, respectively). The amount of dissolved solids was lower (87.0 mg L^{-1}) at sampling point 4. Likewise, the amounts of total and fecal coliforms were lower at sampling point 2 (112 and 20 col 100 mL^{-1}, respectively). The pH of the water was lower at sampling points 3 and 4 (6.8 and 6.9) with respect to the other sampling points, where the pH was higher than 7. It was also determined that only at sampling point 4 was the water conductivity lower than 130 µS cm^{-1}. The analysis of the hydromorphological variables shows that the El Salvador River is not very deep; minimum depths of 0.2 m and maximum depths of 3.2 m were determined along with a minimum velocity of 0.1 and a maximum of 13 m s^{-1}. Finally, it is important to note that the width of the river fluctuated in the analyzed section from points 1 to 7 (11.1, 17.0, 5.1, 9.0, 10.0, 9.0, and 9.0 m).

The water reports also determined that the presence of N-NO_2, BOD_5, lead (Pb), nickel (Ni), and cadmium (Cd) in the seven sampling points were <0.05, 0.0, <0.30, <0.20, and <0.03, respectively. The turbidity of the river at the first three sampling points was 0, and from points 4, 5, 6, and 7, average values of 7.5, 12.2, 12.8, and 19.5 were obtained, respectively.

The correlation analysis for April identified a highly significant positive correlation between total dissolved solids (TDS) and nitrates (0.75), dissolved oxygen (0.79), and conductivity (0.99) as well as between conductivity and dissolved oxygen (0.83) (Figure 2). In May, a highly significant correlation was found between conductivity and TDS (1.0) (Figure 3). In June, highly significant correlations were found between water temperature and TDS (0.84) and conductivity (0.84), between TDS and dissolved oxygen (0.88) and TDS (1.0), and between dissolved oxygen and conductivity (0.88) (Figure 4).

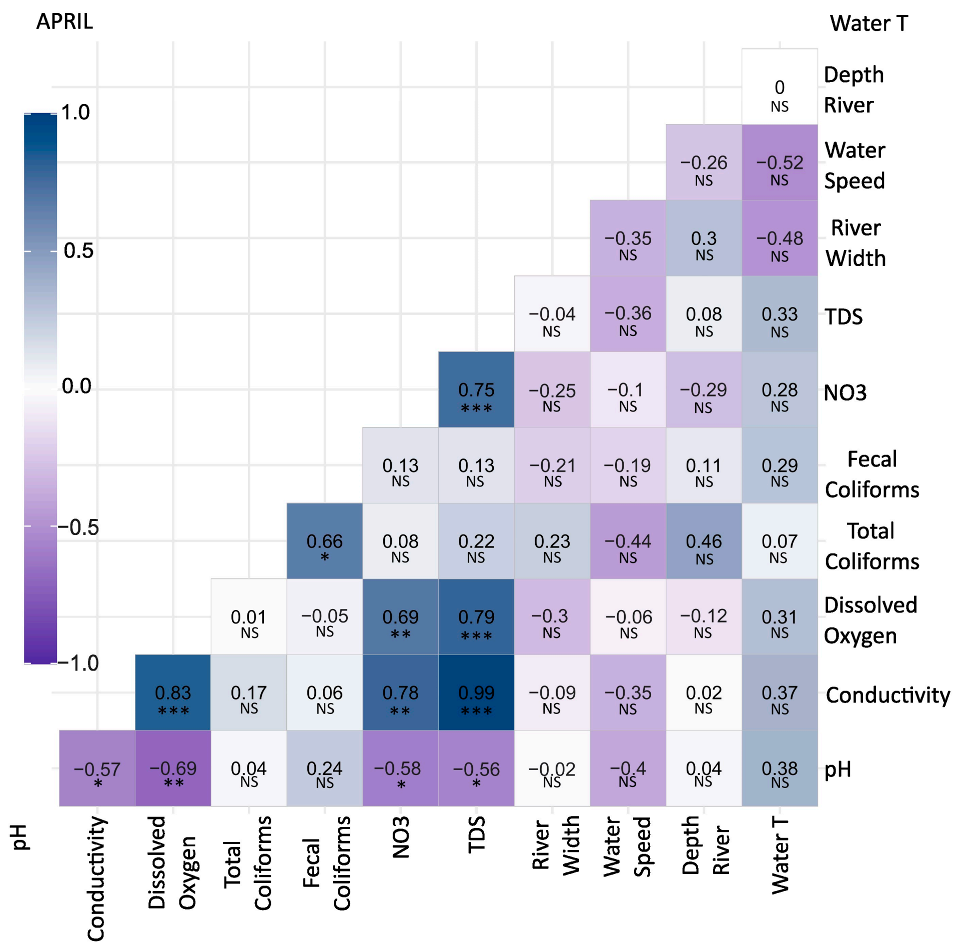


Figure 2. Correlation matrix of environmental and hydromorphological variables in April (* significant at 90%, * *significant at 95%, *** significant at 99%, NS not significant).

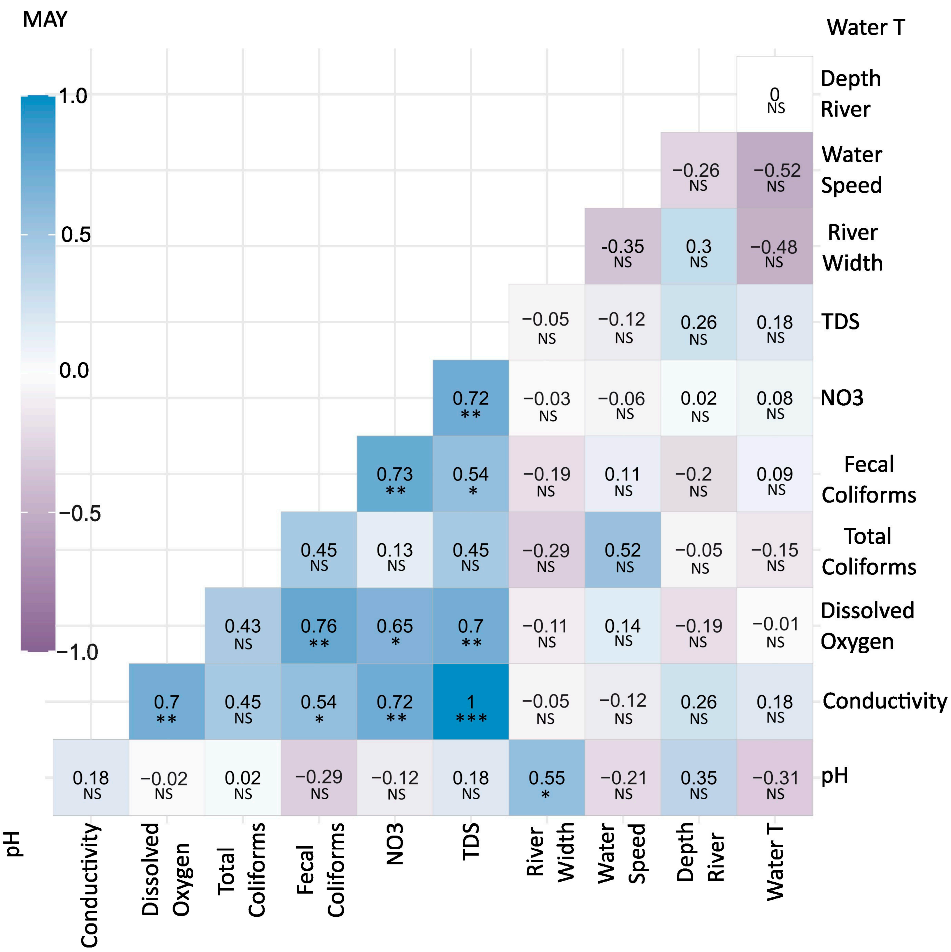


Figure 3. Correlation matrix of environmental and hydromorphological variables in May (* significant at 90%, ** significant at 95%, *** significant at 99%, NS not significant).

In addition, in April, a slightly negative correlation was observed between pH and conductivity, dissolved oxygen, nitrates, and dissolved solids (−0.57, −0.69, −0.58, and −0.56) (Figure 2). In May, there were non-significant negative correlations (Figure 3), and in June, significant negative correlations were again determined between river width and conductivity (−0.57), dissolved oxygen (−0.57), and TDS (−0.57), between fecal coliforms and conductivity (−0.57), and between pH and dissolved oxygen (−0.66) and conductivity (−0.55) (Figure 4). The non-correlation of these variables with the pH of the water is possibly due to the fact that the pH remained in acceptable ranges (6.5 to 8.5); that is, it is appropriate for the subsistence of many biological systems [34]. Finally, the correlation of nitrates with some variables in April, May, and June is possibly due to anthropogenic activities, such as growing crops with the intensive use of agrochemicals.

The water quality index (Q value) from Supplemental Table 2 was multiplied by the *wi* (Supplementary Material S1) of the physicochemical and biological parameters shown in Supplemental Table 1. The calculated values show that at sampling points 1, 2, and 3, Q was 87; at sampling point 4, it was 86; at points 5 and 6, the value was 85; and at point 7, it was 84. It was therefore determined that the water quality index was 86, which corresponds to good water quality.

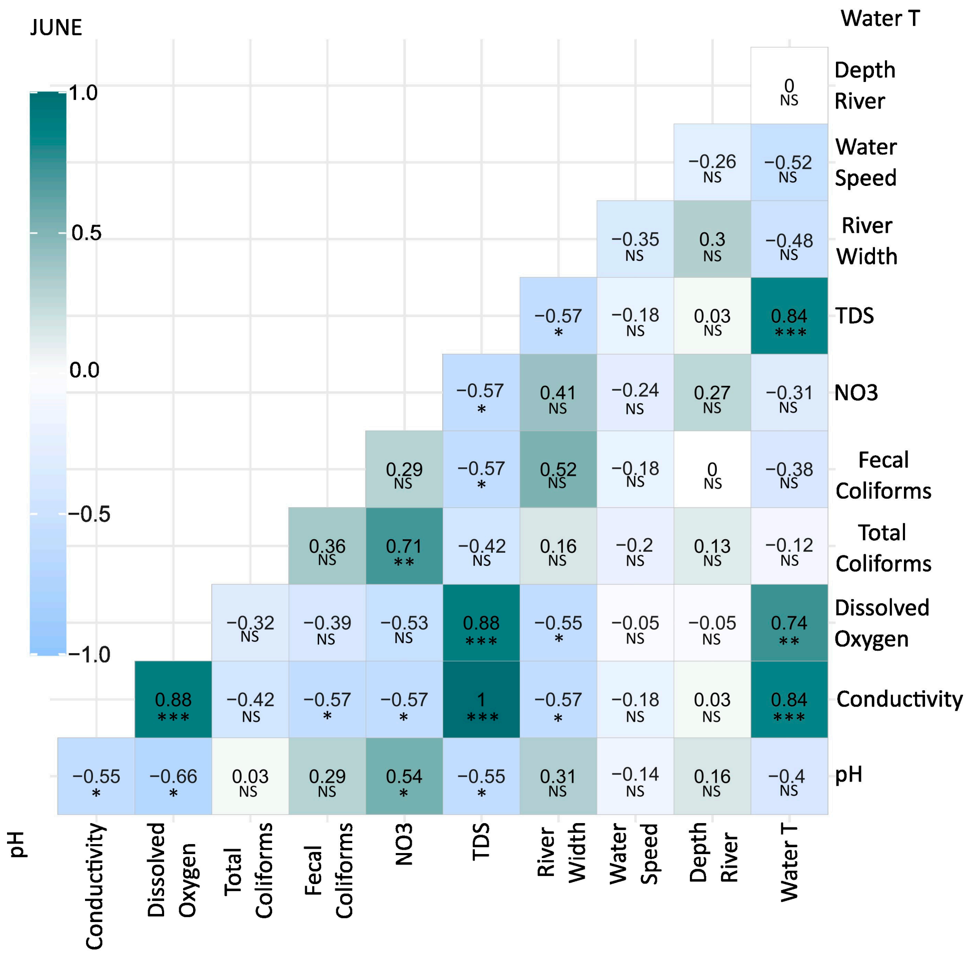


Figure 4. Correlation matrix of environmental and hydromorphological variables in June (* significant at 90%, ** significant at 95%, *** significant at 99%, NS not significant).

4. Discussion

In the El Salvador River, located in the Tres de Noviembre parish in the La Joya de los Sachas canton, the DO, nitrate content, and TDS were found to be 1.7 to 5.19, 23.6 to 44.3, and 87 to 95.43 mg L^{-1}, respectively, values that are lower (DO: 3.08 to 2.72) and higher (nitrates: 0.40 to 0.58; TDS: 53.9 to 73.6 mg L^{-1}) than those reported by Vargas-Tierras et al. [18] in a study conducted in the Yanaquincha River located in the same canton.

The presence of nitrates in the El Salvador River exceeded the permissible limits (20 mg L^{-1}), mainly due to the dragging or draining of nitrogen (fertilizers) used for agricultural activities [38]. For this reason, as the river continues its course and agricultural activities increase, the nitrate content also increases. The determination of DO is fundamental in water quality evaluations because of the aerobic respiration processes of aquatic organisms [39]. In this study, the DO at sampling points 1 and 2 was below 3 mg L^{-1}, possibly compromising aquatic life. Likewise, the TDS content at the sampling points was between 80 and 96 mg L^{-1}. We do not know if these values are within the minimum or maximum permissible limits stipulated by the Ministry of the Environment, Water, and Ecological Transition; however, it is known that the main sources that cause high concentrations of TDS are eroded soils, agricultural waste, livestock waste, and other human activities [33]. The water temperature at the sampling points was within the parameters established as normal (24.4 to 30.0 °C), i.e., a good condition for the ecosystem [34].

When comparing the results of this study carried out on the El Salvador River with the values suggested by Effendi [21] in Government Regulation No. 82/2001, class III water quality for fisheries and livestock, it was determined that nitrates and conductivity exceeded the values reported in the standard (20 mg L^{-1} and 50 µS cm^{-1}, respectively). And, when comparing these values of nitrates obtained with those issued by the Ministry of the Environment, Water, and Ecological Transition, it was determined that the values of nitrates and conductivity exceeded the values reported in the standard (20 mg L^{-1} and 50 µS cm^{-1}, respectively) [22]. Compared to Supplemental Table 2 of Supplementary Material S3: admissible quality criteria for the preservation of aquatic life and other wildlife in fresh, marine, and estuarine waters and Supplemental Table 4 of Supplementary Material S3: parameters of water quality levels for irrigation, our values exceeded theirs by 13 mg L^{-1} and >30 µS cm^{-1}, respectively (Supplementary Material S1).

The presence of nitrates in the El Salvador River is possibly due to the presence of permanent (*Theobroma cacao* L., *Coffe canephora*, and *Elaeis guineensis*) and transitory crops (*Zea mays*, *Arachis hypogaea*, *Oriza sativa*, *Colocasia esculenta*, and *Musa* spp.) [21] located around the river (Figure 1), with transient crops being the most demanding in the use of synthetic fertilizers. In Guatemala and Honduras, a study showed that the leaching and runoff of fertilizers used in agriculture and human manure caused nitrogen contamination of 92% and 55.5%, respectively, in surface water and groundwater [40,41], causing the development of invasive macrophytes and the eutrophication of the river [42]. This statement is corroborated by Zaresefat et al. [43], who point out that the concentration of nitrates in rivers is due to the widespread use of nitrogen fertilizers in high-yield crops; they also mention that high nitrogen inputs can negatively affect human health and aquatic ecosystems. Zhang et al. [44] mention that several studies have confirmed that both cultivated and urban areas export a greater amount of nitrates to river water compared to forested and pasture areas and that the concentration of nitrates in rivers occurs due to an increase or decrease in surface runoff, land use transformation, and human activities. On the other hand, Pacheco and Sanches Fernandes [45] point out that human activity has a direct and indirect impact on the quality of river waters.

Likewise, changes in conductivity in the El Salvador River go hand in hand with the presence of nitrates and may indicate a deterioration in the ecological state of this water system, mainly due to the presence or absence of aquatic organisms [46]. In this situation, this parameter is widely used in monitoring studies as an indicator of general inorganic pollution of the water system (catchment pressure) and is sometimes used as a complementary indicator of the progress of eutrophication caused by human activities [46–48].

On the other hand, the positive correlations between TDS and nitrates, dissolved oxygen, conductivity, and water temperature in April, May, and June are possibly due to the fact that the variables are always related. Chibinda et al. [49] mention that conductivity is closely related to the content of total dissolved solids because they are proportional to conductivity. Zhang et al. [50] assert that the correlation between conductivity and dissolved oxygen is a key factor that allows us to predict the concentration of nitrogen in the water. Castro et al. [51] also point out that values for nitrates, dissolved oxygen, and conductivity were related in sites where the land use around the river is for agricultural purposes due to inorganic fertilizer intake [34]; for example, along the Bermúdez River in Costa Rica where coffee is grown, these parameters were highly correlated. In the Puyo River, located in the central Ecuadorian Amazon Region, dissolved oxygen and nitrates were also found to be correlated [52]. The relationship between temperature and conductivity and TDS is corroborated by Adjovu et al. and Dewangan et al. [53,54], who maintain that as the water temperature increases, the ions present in the water become more active and move rapidly, which leads to an increase in conductivity and TDS. For this reason, the evaluation of temperature must be considered in these water quality studies.

The correlation between total soluble solids was corroborated by Sugiarti et al. [55] in a study conducted in Indonesia, where it was determined that current land use behaved as an inverse proxy, i.e., land use was mainly related to an increase in TDS [56]. The correlation with nitrates is possibly due to the current modern use of the soil [57].

From the results obtained in the monitoring of the El Salvador River, it can be concluded, based on the physical, chemical, and biological characteristics, that the water quality index was good (86). Throughout the river, it was determined that the water quality patterns were similar, showing minimal variations and mostly acceptable levels at the seven sampling points. It can be indicated that human activities in the tourist centers located along the river have not yet generated water quality problems. In the province of Orellana, some water quality studies have been carried out using the biotic quality index and physical, chemical, and biological analyses, and it has been determined that the water quality of other rivers (Rumiyacu, Suno, and Yanaquincha) can still be categorized as average or good [18,58,59]. In Pastaza, it was determined that two rivers used for bathing are contaminated [60]. In view of this situation, it is important to carry out periodic monitoring of the water and surrounding areas in order to take immediate corrective actions.

On the other hand, it is important to mention that the "good" water quality index in the El Salvador River may be applicable if this river were to be used only for recreational activities, as shown in Supplemental Table 4 (Supplementary S3): water quality criteria for recreational purposes by primary contact [22], where nitrates are excluded as an evaluation parameter. However, the presence of this molecule in the El Salvador River suggests that it is being exported by surface runoff [44] to the river from the surrounding crops located along the banks. For this reason, it is recommended that periodic nitrate sampling be carried out in this river in order to alert local authorities about possible water contamination and, above all, to take corrective actions to prevent nitrate levels from exceeding 50 mg L^{-1}, the value established in Supplemental Table 1 (Supplementary S3): quality criteria used for water sources for human consumption.

Finally, it is worth mentioning that in the Ecuadorian Amazon Region, there are no systems for the treatment of contaminated water. An alternative for decision-makers could be the use of bioengineering systems with aquatic plants, such as helophytes, which are used to reduce excess nitrogen in the water [61]. First, it is suggested that aquatic plants with this potential in the region be identified, then experimental studies should be carried out to select plants with purifying capacity, and finally, these processes should be implemented in situ to further explore the potential of helophytes in different environmental contexts and evaluate their long-term effectiveness in improving water quality and aquatic biodiversity. In addition, collaboration between scientists, engineers, and environmental managers will be essential in order to design and implement effective and sustainable bioengineering systems that harness the power of aquatic plants for the restoration and conservation of aquatic ecosystems.

5. Conclusions

The water quality index of the El Salvador River showed that this water is good enough to be used for recreational activities; however, the nitrate content in the river exceeded the values determined in Reform Book VI of the unified text of Secondary Legislation of the Ecuadorian Environment Ministry—Ministerial Agreement 097-A and Decree No. 115/2003, class III. Therefore, it is advisable to carry out periodic sampling to compare the behavior of this molecule over time.

It is important to point out that if agricultural and livestock activities intensify around the river, the nitrate content could increase, becoming a potential risk to human health in most of the communities of the Tres de Noviembre parish, with children being more vulnerable than adults to the carcinogenic effects caused by this contamination.

It is advisable to implement bioengineering systems that integrate helophyte plants, especially in environments with water pollution problems. Further research is recommended to explore their effectiveness in different environmental contexts and to assess their long-term impact on water quality and aquatic biodiversity.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/w16091259/s1; The Supplementary S1 and S2 shows Table S1, relative weights used for the determination of the WQI. Table S2, Water Quality Index (WQI). The Supplementary S3, shows the regulations of Reform Book VI of the Unified Text of Secondary Legislation of the Ecuadorian Environment Ministry—Ministerial Agreement 097-A, specifically in the Supplemental

Table 1: quality criteria for water sources for human and domestic consumption; Supplemental Table 2: water quality criteria for the preservation of aquatic life and other wildlife in fresh waters, and in marine and estuarine waters; Supplemental Table 4, parameters of water quality levels for irrigation; and Supplemental Table 6, water quality criteria for recreational purposes through primary contact; and Supplementary S4, contain the table Class III water quality standard for fish and livestock as stipulated in Government Regulation no. 82/2001, cited by Effendi in the study entitled: Water quality status of Ciambulawung River, Banten Province, based on pollution index and NSF-WQI.

Author Contributions: Conceptualization: T.V.-T., S.P., G.C. and M.J.-G.; methodology: T.V.-T., S.P. and G.C.; statistical analysis: F.P.; writing—original draft preparation: T.V.-T., M.J.-G., V.M-L., M.M.-L. and W.V.-C.; writing—review and editing: T.V.-T., M.J.-G., V.M.-L., M.M.-L. and W.V.-C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Gorgoglione, A.; Gregorio, J.; Ríos, A.; Alonso, J.; Chreties, C.; Fossati, M. Influence of Land Use/Land Cover on Surface-Water Quality of Santa Lucía River, Uruguay. *Sustainability* **2020**, *12*, 4692. [CrossRef]
2. Xu, G.; Li, P.; Lu, K.; Tantai, Z.; Zhang, J.; Ren, Z.; Wang, X.; Yu, K.; Shi, P.; Cheng, Y. Seasonal Changes in Water Quality and Its Main Influencing Factors in the Dan River Basin. *Catena* **2019**, *173*, 131–140. [CrossRef]
3. Shi, P.; Zhang, Y.; Li, Z.; Li, P.; Xu, G. Influence of Land Use and Land Cover Patterns on Seasonal Water Quality at Multi-Spatial Scales. *Catena* **2017**, *151*, 182–190. [CrossRef]
4. Pettit, N.E.; Jardine, T.D.; Hamilton, S.K.; Sinnamon, V.; Valdez, D.; Davies, P.M.; Douglas, M.M.; Bunn, S.E. Seasonal Changes in Water Quality and Macrophytes and the Impact of Cattle on Tropical Floodplain Waterholes. *Mar. Freshw. Res.* **2012**, *63*, 788–800. [CrossRef]
5. Rodrigues, V.; Estrany, J.; Ranzini, M.; de Cicco, V.; Martín-Benito, J.M.T.; Hedo, J.; Lucas-Borja, M.E. Effects of Land Use and Seasonality on Stream Water Quality in a Small Tropical Catchment: The Headwater of Córrego Água Limpa, São Paulo (Brazil). *Sci. Total Environ.* **2018**, *622–623*, 1553–1561. [CrossRef] [PubMed]
6. Pérez-Gutiérrez, J.D.; Paz, J.O.; Tagert, M.L.M. Seasonal Water Quality Changes in On-Farm Water Storage Systems in a South-Central U.S. Agricultural Watershed. *Agric. Water Manag.* **2017**, *187*, 131–139. [CrossRef]
7. Organización de las Naciones Unidas para la Agricultura y Alimentación Contaminación del agua por la Agricultura. Available online: https://www.fao.org/3/cb7654es/online/src/html/chapter-1-5.html (accessed on 19 February 2024).
8. Tu, J. Spatial Variations in the Relationships between Land Use and Water Quality across an Urbanization Gradient in the Watersheds of Northern Georgia, USA. *Environ. Manag.* **2013**, *51*, 1–17. [CrossRef]
9. Chen, Q.; Mei, K.; Dahlgren, R.A.; Wang, T.; Gong, J.; Zhang, M. Impacts of Land Use and Population Density on Seasonal Surface Water Quality Using a Modified Geographically Weighted Regression. *Sci. Total Environ.* **2016**, *572*, 450–466. [CrossRef] [PubMed]
10. Díaz-Casallas, D.M.; Castro-Fernández, M.F.; Bocos, E.; Montenegro-Marin, C.E.; González Crespo, R. 2008–2017 Bogota River Water Quality Assessment Based on the Water Quality Index. *Sustainability* **2019**, *11*, 1668. [CrossRef]
11. Choque-Quispe, D.; Froehner, S.; Palomino-Rincón, H.; Peralta-Guevara, D.E.; Barboza-Palomino, G.I.; Kari-Ferro, A.; Zamalloa-Puma, L.M.; Mojo-Quisani, A.; Barboza-Palomino, E.E.; Zamalloa-Puma, M.M.; et al. Proposal of a Water-Quality Index for High Andean Basins: Application to the Chumbao River, Andahuaylas, Peru. *Water* **2022**, *14*, 654. [CrossRef]
12. Chidiac, S.; El Najjar, P.; Ouaini, N.; El Rayess, Y.; El Azzi, D. A Comprehensive Review of Water Quality Indices (WQIs): History, Models, Attempts and Perspectives. *Rev. Environ. Sci. Biotechnol.* **2023**, *22*, 349–395. [CrossRef] [PubMed]
13. Universidad Pamplona Índice de Calidad (ICAs) y de Cotaminación (ICOs) del agua de Importancia Mundial. Available online: https://www.unipamplona.edu.co/unipamplona/portalIG/home_1/recursos/01_general/18072016/google_busqueda.jsp (accessed on 15 February 2024).
14. Sakke, N.; Jafar, A.; Dollah, R.; Asis, A.H.B.; Mapa, M.T.; Abas, A. Water Quality Index (WQI) Analysis as an Indicator of Ecosystem Health in an Urban River Basin on Borneo Island. *Water* **2023**, *15*, 2717. [CrossRef]
15. Masood, A.; Niazkar, M.; Zakwan, M.; Piraei, R. A Machine Learning-Based Framework for Water Quality Index Estimation in the Southern Bug River. *Water* **2023**, *15*, 3543. [CrossRef]
16. Zhang, F.; Chan, N.W.; Liu, C.; Wang, X.; Shi, J.; Kung, H.-T.; Li, X.; Guo, T.; Wang, W.; Cao, N. Water Quality Index (WQI) as a Potential Proxy for Remote Sensing Evaluation of Water Quality in Arid Areas. *Water* **2021**, *13*, 3250. [CrossRef]
17. Najafzadeh, M.; Basirian, S. Evaluation of River Water Quality Index Using Remote Sensing and Artificial Intelligence Models. *Remote Sens.* **2023**, *15*, 2359. [CrossRef]
18. Vargas-Tierras, T.; Suárez-Cedillo, S.; Morales-León, V.; Vargas-Tierras, Y.; Tinoco-Jaramillo, L.; Viera-Arroyo, W.; Vásquez-Castillo, W. Ecological River Water Quality Based on Macroinvertebrates Present in the Ecuadorian Amazon. *Sustainability* **2023**, *15*, 5790. [CrossRef]

19. Gobierno Parroquial Tres de Noviembre Clima. Available online: https://www.tresdenoviembre.gob.ec/laparroquia/datos-generales/clima.html (accessed on 24 January 2024).
20. Gobiernno Municipal La Joya de los Sachas Plan de Desarrollo y Ordenamiento Territorial 2019–2023. Available online: https://mega.nz/download (accessed on 23 December 2022).
21. Gobierno Parroquial Tres de Noviembre Plan de Desarrollo y Ordenamiento Territorial Del Gobierno Autónomo Descentralizado Parroquial Rural Tres de Noviembre. Available online: https://tresdenoviembre.gob.ec/gad-parroquial/plan-de-desarrollo.html (accessed on 16 February 2024).
22. Ministerio de Ambiente Acuerdo Ministerial 097-A, Anexos de Normativa, Reforma Libro vi del Texto Unificado de Legislacion Secundaria del Ministerio del Ambiente | Ecuador-Guía Oficial de Trámites y Servicios. Available online: https://www.gob.ec/regulaciones/acuerdo-ministerial-097-anexos-normativa-reforma-libro-vi-texto-unificado-legislacion-secundaria-ministerio-ambiente (accessed on 19 February 2024).
23. Effendi, H. River Water Quality Preliminary Rapid Assessment Using Pollution Index. *Procedia Environ. Sci.* **2016**, *33*, 562–567. [CrossRef]
24. Larrea, J.A.L.; Romeu, B.; Moya, D.L.; Rojas, M.M.R. Aspectos fundamentales del monitoreo de calidad de las aguas: El río almendares como caso de estudio. *Rev. Cen. Cienc. Biol.* **2022**, *53*, 148–159.
25. Instituto Geográfico Militar del Ecuador Cartografía de Libre Acceso Escala 50 k—Geoportal Ecuador. Available online: https://www.geoportaligm.gob.ec/portal/index.php/cartografia-de-libre-acceso-escala-50k/ (accessed on 20 February 2024).
26. Ministerio de Ambiente, Agua y Transición Ecológica Mapa de Cobertura y Uso de La Tierra (CUT 2022). Available online: http://ide.ambiente.gob.ec:8080/mapainteractivo/ (accessed on 20 February 2024).
27. Instituto Ecuatoriano de Normalización (INEN). *NTE INEN 2169: Agua. Calidad Del Agua. Muestreo. Manejo y Conservación De Muestras*; INEN: Quito, Ecuador, 1998.
28. Pauta, G.; Velazco, M.; Gutierrez, D.; Vázquez, G.; Rivera, S.; Morales, O.; Abril, A. Evaluación de la calidad del agua de los ríos de la ciudad de Cuenca, Ecuador. *Maskana* **2019**, *10*, 76–88. [CrossRef]
29. Instituto Ecuatoriano de Normalización (INEN). *NTE INEN 2226: Agua. Calidad del Agua. Muestreo. Diseño de los Programas de Muestreo*; INEN: Quito, Ecuador, 2000.
30. Ann, M.; Franson, H. *Métodos Normalizados Para el Análisis de Aguas Potables y Residuales APHA-AWWA-WPCF 978-84-7978-031-9*, 17th ed.; Díaz de Santos, S.A.: Madrid, España, 1992.
31. Shahady, T.; Montero-Ramírez, J.J. End-Point Predictors of Water Quality in Tropical Rivers. *Pollutants* **2023**, *3*, 461–476. [CrossRef]
32. Akhtar, N.; Ishak, M.I.S.; Ahmad, M.I.; Umar, K.; Md Yusuff, M.S.; Anees, M.T.; Qadir, A.; Ali Almanasir, Y.K. Modification of the Water Quality Index (WQI) Process for Simple Calculation Using the Multi-Criteria Decision-Making (MCDM) Method: A Review. *Water* **2021**, *13*, 905. [CrossRef]
33. Ewaid, S.H.; Abed, S.A.; Al-Ansari, N.; Salih, R.M. Development and Evaluation of a Water Quality Index for the Iraqi Rivers. *Hydrology* **2020**, *7*, 67. [CrossRef]
34. Gabriela Pérez Castillo, A.; Rodríguez, A. Indice fisicoquímico de la calidad de agua para el manejo de lagunas tropicales de inundación. *RBT* **2007**, *56*, 1905–1918. [CrossRef]
35. Patel, D.D.; Mehta, D.J.; Azamathulla, H.M.; Shaikh, M.M.; Jha, S.; Rathnayake, U. Application of the Weighted Arithmetic Water Quality Index in Assessing Groundwater Quality: A Case Study of the South Gujarat Region. *Water* **2023**, *15*, 3512. [CrossRef]
36. Silva, P.L.C.; Borges, A.C.; Lopes, L.S.; Rosa, A.P. Developing a Modified Online Water Quality Index: A Case Study for Brazilian Reservoirs. *Hydrology* **2023**, *10*, 115. [CrossRef]
37. R Core Team R Core Team-CNET. Download. Available online: https://download.cnet.com/developer/r-core-team/i-6264363/ (accessed on 11 January 2023).
38. Li, B.; Yang, G.; Wan, R. Multidecadal Water Quality Deterioration in the Largest Freshwater Lake in China (Poyang Lake): Implications on Eutrophication Management. *Environ. Pollut.* **2020**, *260*, 114033. [CrossRef] [PubMed]
39. Ahmed, S.; Griffin, T.S.; Kraner, D.; Schaffner, M.K.; Sharma, D.; Hazel, M.; Leitch, A.R.; Orians, C.M.; Han, W.; Stepp, J.R.; et al. Environmental Factors Variably Impact Tea Secondary Metabolites in the Context of Climate Change. *Front. Plant Sci.* **2019**, *10*, 939. [CrossRef] [PubMed]
40. Rivas, Z.; Sánchez, J.; Troncone, F.; Márquez, R.; de Medina, H.L.; Colina, M. Nitrógeno y Fósforo Totales de los Ríos Tributarios al Sistema Lago de Maracaibo, Venezuela. *Interciencia* **2009**, *34*, 308–314.
41. Xie, H.; Huang, C.; Li, J.; Zhang, Y.; Xu, X.; Liu, D.; Ouyang, Z. Strong Precipitation and Human Activity Spur Rapid Nitrate Deposition in Estuarine Delta: Multi-Isotope and Auxiliary Data Evidence. *Int. J. Environ. Res. Public Health* **2021**, *18*, 6221. [CrossRef]
42. Montemurro, D.G. *Balance de Nutrientes y Eutrofización en Ríos y Embalses de la Cuenca del Río Negro (Uruguay)*; Universidad Republica de Uruguay: Paso Bonito, Cuba, 2017.
43. Zaresefat, M.; Hosseini, S.; Ahrari Roudi, M. Addressing Nitrate Contamination in Groundwater: The Importance of Spatial and Temporal Understandings and Interpolation Methods. *Water* **2023**, *15*, 4220. [CrossRef]
44. Zhang, X.; Zhang, Y.; Shi, P.; Bi, Z.; Shan, Z.; Ren, L. The Deep Challenge of Nitrate Pollution in River Water of China. *Sci. Total Environ.* **2021**, *770*, 144674. [CrossRef] [PubMed]

45. Pacheco, F.A.L.; Sanches Fernandes, L.F. Environmental Land Use Conflicts in Catchments: A Major Cause of Amplified Nitrate in River Water. *Sci. Total Environ.* **2016**, *548–549*, 173–188. [CrossRef] [PubMed]
46. Arciszewski, T.J.; Roberts, D.R. Analyzing Relationships of Conductivity and Alkalinity Using Historical Datasets from Streams in Northern Alberta, Canada. *Water* **2022**, *14*, 2503. [CrossRef]
47. Beeton, A.M. Eutrophication of the St. Lawrence Great Lakes. *Limnol. Oceanogr.* **1965**, *10*, 240–254. [CrossRef]
48. Shannon, E.E.; Brezonik, P.L. Euthrophication Analysis: A Multivariate Approach. *J. Sanit. Eng. Div.* **1972**, *98*, 37–57. [CrossRef]
49. Chibinda, C.; Arada-Pérez, D.M.L.A.; Pérez-Pompa, N. Caracterización Por Métodos Físico-Químicos y Evaluación Del Impacto Cuantitativo de las Aguas del Pozo la Calera. *Rev. Cuba. Quím.* **2017**, *29*, 303–321.
50. Zhang, D.; Wang, P.; Cui, R.; Yang, H.; Li, G.; Chen, A.; Wang, H. Electrical Conductivity and Dissolved Oxygen as Predictors of Nitrate Concentrations in Shallow Groundwater in Erhai Lake Region. *Sci. Total Environ.* **2022**, *802*, 149879. [CrossRef] [PubMed]
51. Castro, L.; Fraile, J.; Reynolds Vargas, J. Conductividad, oxígeno disuelto, PH y temperatura en el rio Bermudez (Costa Rica) y su relación con el uso del suelo en la cuenca. *Uniciencia* **1996**, *13*, 27–34.
52. Abril Saltos, R.V.; Rodríguez Badillo, L.M.; Sucoshañay Villalba, D.J.; Bucaram Visuma, E.M. Caracterización Preliminar de Calidad de Aguas En Subcuenca Media Del Río Puyo. *Ing. Hidrául. Ambient.* **2017**, *38*, 59–72.
53. Adjovu, G.E.; Stephen, H.; Ahmad, S. A Machine Learning Approach for the Estimation of Total Dissolved Solids Concentration in Lake Mead Using Electrical Conductivity and Temperature. *Water* **2023**, *15*, 2439. [CrossRef]
54. Dewangan, S.K.; Shrivastava, S.; Kadri, M.; Saruta, S.; Yadav, S.; Minj, N. Temperature effect on electrical conductivity (EC) & total dissolved solids (TDS) of water a riview. *Int. J. Res. Anal. Rev.* **2023**, *10*, 514–520.
55. Sugiarti; Rohaningsih, D.; Aisyah, S. Study of Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) in Estuaries in Banten Bay Indonesia. *IOP Conf. Ser. Earth Environ. Sci.* **2023**, *1201*, 012045. [CrossRef]
56. Kent, R.; Landon, M.K. Trends in Concentrations of Nitrate and Total Dissolved Solids in Public Supply Wells of the Bunker Hill, Lytle, Rialto, and Colton Groundwater Subbasins, San Bernardino County, California: Influence of Legacy Land Use. *Sci. Total Environ.* **2013**, *452–453*, 125–136. [CrossRef] [PubMed]
57. Burow, K.R.; Shelton, J.L.; Dubrovsky, N.M. Regional Nitrate and Pesticide Trends in Ground Water in the Eastern San Joaquin Valley, California. *J. Environ. Qual.* **2008**, *37*, S-249–S-263. [CrossRef] [PubMed]
58. Armijos Muñoz, T.E.; Sánchez Vargas, K.A. Evaluación de la Calidad de Agua del Río Rumiyacu Mediante la Utilización de Bioindicadores en la Parroquia Dayuma Cantón Orellana Provincia de Orellana. Bachelor's Thesis, Universidad Estatal Amazónica, Puyo, Ecuador, 2019.
59. Tapia Lara, E.A. *Calidad Fisicoquímica y Microbiológica del Agua del Río Suno Previo a su Ingreso en la Planta de Tratamiento Cantón Loreto*; Universidad Central del Ecuador: Quito, Ecuador, 2021.
60. Sucoshañay, D.; Gutiérrez, J.; García, A.; Ledesma, R.; Kuásquer, E.; Martínez, G. Evaluación de La Calidad de Las Aguas Superficiales de La Cuenca Del Río Puyo de La Amazonia Ecuatoriana a Partir de Un Índice Integrador (ICA_sp). *Rev. Cien. Tierra Esp.* **2015**, *16*, 225–236.
61. Ribot, M.; Cochero, J.; Vaessen, T.N.; Bernal, S.; Bastias, E.; Gacia, E.; Sorolla, A.; Sabater, F.; Martí, E. Leachates from Helophyte Leaf-Litter Enhance Nitrogen Removal from Wastewater Treatment Plant Effluents. *Environ. Sci. Technol.* **2019**, *53*, 7613–7620. [CrossRef]