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Comparison between Regionalized Minimum Reference Flow and On-Site Measurements in Hydrographic Basins of Rural Communities in the State of Goiás, Brazil

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Abstract: Reference flows are important variables for assessing water availability in Brazil, as well as in rural communities in the state of Goiás (Brazil). However, as there is a lack of flowrate data and measurement points, regionalization methods have been used for forecasting the minimum reference flow (Q_{ref}) allowed for maintaining water uses. The present research covered 92 hydrographic basins within 46 selected rural communities in the state of Goiás, and 21 basins were selected for carrying out on-site flow measurements, as well as for Q_{ref} estimation following three regionalization methodologies. Results show a large variation between the values measured and estimated by the three methodologies, but the statistical analysis found regression equations of one of the methods more suitable for application in rural hydrograph basins of Goiás.

Keywords: water availability; reference flow; flow regionalization; rural communities; water security

1. Introduction

The availability of water resources in quantity and quality are fundamental for the development of economic activities, as well as for maintaining water uses (e.g., agricultural irrigation, drinking water supply, and industrial use). Hydrographic basins are planning and management units of integrated water management, playing a relevant role in the maintenance of water resources for present and future generations. The rational and integrated use of water for prevention and defense against critical hydrological events is nowadays a priority around the world due to the effects of climate change on water availability and its quality [1–3], which will bring the occurrence of extreme hydrometeorological events such as floods and drought.

In Brazil, Federal Law No. 9.433 created the National Water Resources Policy (PNRH) [4], which is the main tool for integrated water management plans. The assessment of water availability may be performed through minimum, mean, and maximum flows, combined with the variation in rainfall [5]. The minimum flow (ecological flow) in watercourses indicates the natural minimal water availability for satisfying the uses in a hydrographic basin and is a suitable variable for water management, especially for conflict management in water scarcity scenarios [6].

In Goiás, Resolution No. 22/2019 [7] defines as a reference for water availability the minimum flow that guarantees 95% of flow rate over time in surface waters (Q_{95}) for all water uses. According to a survey by Honório [8], the same criterion was adopted in other states of Brazil (e.g., Rio de Janeiro, Espírito Santo, Paraná, Mato Grosso, Mato Grosso do Sul, among others). However, the states of Minas Gerais and São Paulo adopt as reference for issuing water use licenses the minimum flow of a seven-day duration event and ten-year return period ($Q_{7,10}$). Specific flow per unit of area (Q_{spe}) can also be calculated.

Hydrographic basins in rural areas of Brazil are not commonly monitored like those in urban centers. Rural settlements located in the Brazilian semi-arid region face serious obstacles in terms of water supply and economic growth due to water scarcity [9]. Moreover, the existing measuring stations have some problems with data acquisition, such as missing and inconsistent data, which does not allow performing accurate analyses on water availability. The situation in the semi-arid region of Brazil is the most complex one in terms of pressure on water resources, and it brings concerns about the effects of climate change as it is observed in other semi-arid regions around the world [10,11]. This occurs more frequently in medium and small hydrographic basins [12], and the catchments with inadequate streamflow data are classified as ungauged [13]. For example, in the rural settlement of Santa Mônica (Paraíba State), the situation is alarming because there are no surface or underground sources for satisfying the water demand. Thus, residents are completely dependent on water trucks, excluding the possibility of agricultural activities.

Therefore, in the absence of suitable historical data on precipitation and/or watercourse flows, methods for transferring information between regions within a homogeneous area, called flow regionalization, have allowed filling the gap in hydrological data in areas with little or no information [13–17]. Regionalization rainfall vs. runoff or watercourse flow vs. drainage area methods allow forecasting watercourse flows at ungauged catchments through the transfer of hydrologic information, such as flow rates and/or precipitation, from gauged to ungauged catchments, using regression analysis [14]. Models are normally calibrated with observations/measurements from gauged watercourses that can then be used to quantify watercourses' characteristics [17]. Generally, the studies on regionalization flow compare the estimated flow (e.g., Q_{95} or Q_{spe}) with that observed/measured in measuring points, introducing several uncertainties, and differences between estimated and observed flows can vary significantly [14,15]. This methodology has shown satisfactory results and can provide agility in decision-making processes, but it does not rule out the need for monitoring hydrological variables, since it can tend towards over-parameterization [8,13,14].

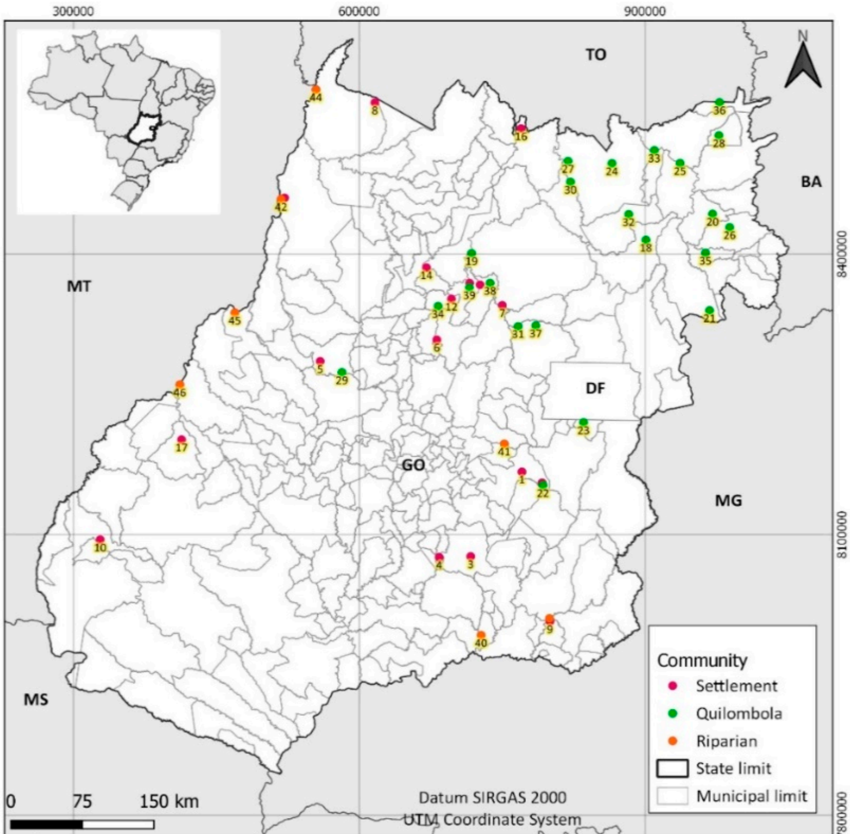
The state of Goiás is attempting to solve the problem of water management in hydrographic basins that do not have enough hydrological information for calculating the reference flow [7]. The lowest flow (Q_{95}) measured in an area is used as the reference flow (Q_{ref}), preferably in the dry season [18]. Honório (2020) [8], considering the hydrographic basins delimited by the state's environmental agency for issuing water use licenses [7], determined regional regression equations for 12 hydrographic basins using data of Q_{95} and drainage areas from 70 fluviometric stations, following the methodology on regression analysis approved by the PERH (2015) [18]. Costa (2021) [19] defined eight regression model equations for estimating Q_{ref} in eight of the eleven Water Resources Planning and Management Units (UPGRH) of Goiás, using data of Q_{95} and drainage areas from 42 fluviometric stations and following the PERH (2015) [18] methodology.

Therefore, in this study, we aimed to estimate the minimum reference flow (Q_{ref}) in representative hydrographic basins of selected rural communities in the state of Goiás (Brazil), using three regionalization methodologies developed in [8,18,19] and on-site measurements for comparative critical analysis.

2. Materials and Methods

2.1. Study Area

The study area covered 46 selected rural communities (7 riparian communities, 17 settlements, and 22 "quilombola" communities) in the state of Goiás (Figure 1) (Sanitation and Environmental Health in Rural and Traditional Communities in Goiás (SanRural). The state has a tropical climate (Aw) according to the Köppen–Geiger classification with two well-defined seasons, winter (dry) and summer (rainy), with average rainfall ranging from 1200 to 2000 mm, a low thermal amplitude, and an average minimum temperature of 16 °C and a maximum of 34 °C. The state's hydrography is made up of rivers that feed three important hydrographic regions in Brazil (Rio Tocantins, Rio Paranaíba, and Rio São Francisco), which also have a dense drainage network according to data available in the State Geoinformation System (SIEG-GO). The QGis software (version 3.14) was used for delimiting the hydrographic basins and respective areas for each watercourse in the state. In the end, for the hydrographic analysis of the 46 rural communities, 92 hydrographic basins were delimited, covering areas ranging from 0.15 km^2 to 123,349.55 km^2. This large number of basins occurred because some communities are in more than one hydrographic basin.



ID	Community	ID	Community	ID	Community
1	João de Deus	16	Céu Azul	31	Queixo Dantas
2	São Sebastião da Garganta	17	Fortaleza	32	Povoado Moinho
3	Piracanjuba	18	Forte	33	Pelotas
4	Rochedo	19	Rafael Machado	34	Porto Leucádio
5	Arraial das Antas II	20	Extrema	35	Castelo, Retiro e Três Rios
6	Itajá II	21	Flores Velha/Canabrava	36	Taquarussu
7	Julião Ribeiro	22	Almeidas	37	Sumidouro
8	Lageado	23	Mesquita	38	Fazenda Santo Antônio da Laguna
9	Madre Cristina	24	São Domingos	39	Pombal
10	Pouso Alegre	25	Quilombo dos Magalhães	40	Arraial da Ponte
11	Taruma	26	Baco Pari	41	Olho D' Água
12	Monte Moria	27	Povoado Vermelho	42	Landi
13	Santa Fé da Laguna	28	Vazante	43	Povoado Veríssimo
14	São Lourenço	29	Água Limpa	44	Fio Velasco
15	Engenho da Pontinha	30	José de Coleto	45	Itacaiú
				46	Registro do Araguaia

Figure 1. Location of the 46 communities where the water availability analysis was performed.

2.2. Reference Minimum Flow Estimates

The minimum reference flow (Q_{ref}) was estimated for a set of selected hydrographic basins from the 92 initial basins through flow regionalization, based on regression analysis following the methodology presented in PERH (2015) [18], Honório (2020) [8], and Costa (2021) [19]. PERH (2015) [18] has values of Q_{spe} (in L/s.km^2) for all hydrographic basins and UPGRH of Goiás, calculated by the fitting of regression equations between the dependent (Q_{95}) and independent (drainage areas) variables for the main watercourse of the UPGRH as suggested by [20], using historical series of fluviometric stations. Honório (2020) [8] and Costa (2020) [19] proposed flow regionalization equations in the format of Equation (1) for several hydrographic basins in the different UPGRH of Goiás. Q_{ref} is the obtained Q_{95} using the drainage area of the 21 selected hydrographic basins for each UPGRH.

$$Q_{95} = b \times A^c \tag{1}$$

where Q_{95} is the minimum flow that guarantees 95% of flowrate over time in surface waters (reference flow, Q_{ref}); A is the drainage area of the hydrographic basin (km^2); and b and c are regional parameters fitted in the regression analysis.

A stratified probabilistic sampling, with a proportional allocation of the sample and simple random selection without replacement in each stratum [21], was performed to select a sample of hydrographic basins representative of the 92 initially identified hydrographic basins. Ten strata were defined from the 92 hydrographic basins of all rural communities, considering the 11 UPGRH of Goiás [18]: "Alto Araguaia" ("Upper Araguaia"); "Médio Araguaia" ("Upper-middle Araguaia"); "Médio Tocatins" ("Middle Tocantins"); "Almas e afluentes goianos do Maranhão" ("Almas river and goianos tributaries of the Maranhão river"); "Paranã and Correntes"; "Corumbá, Veríssimo, and São Marcos"; "Meia Ponte"; "Vermelho"; "Baixo Paranaíba" ("Lower Paranaíba"); "Afluentes goianos do S. Francisco" ("Goianos tributaries of the S. Francisco river"); and "Turvo e dos Bois" ("Turvo and of the Bois").

The number of basins allocated within each stratum (n_h) was defined by Equation (2) [21].

$$n_h = \frac{N_h}{N} n = \frac{N_h \sum_{i=1}^{H} \frac{N_i}{N} S_i^2}{NV + \sum_{i=1}^{H} \frac{N_i}{N} S_i^2} \tag{2}$$

where N_h is the number of basins in the stratum h, N is the total number of basins in the study population, n is the total sample size, S_h is the h stratum variance, and $V = (E/z_{1-\alpha/2})^2$, where E is the maximum margin of error and $z_{1-\alpha/2}$ is the quantile of the standard normal distribution for a confidence level of $(1 - \alpha) \times 100$.

Statistical analysis was carried out for calculating average means and confidence intervals for flows considering weights according to basins' dimensions. Unbiased estimators for sums, averages, and ratios, considering the sample weights, defined by the inverse of probability inclusion of a population element in the sample, were followed. The average estimator ($\hat{\mu}_y$) of a variable y can be calculated through Equation (3) [22].

$$\hat{\mu}_y = \sum_{i=1}^{n} \frac{x_i}{p_i} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \tag{3}$$

where $w_i = \frac{1}{p_i}$ is the sample weight and p_i is the probability of inclusion of the i-th basin in a sample.

For the specific case of flow averages, the estimates were made using the ratio estimator with auxiliary information on the area, according to Equation (4) [22], considering that a high and significant correlation (<0.90) between the flows and the basin areas was found.

$$\mu_y^R = \frac{\hat{\mu}_y}{\hat{\mu}_x} x \mu_x \tag{4}$$

where $\hat{\mu}_y$ and $\hat{\mu}_x$ are estimates of reference flow (Q_{ref}) and areas (A), respectively, and μ_x is the population average in the area. The median was estimated according to Equation (5) [23].

$$\hat{M} = x_i \frac{F(x_{i+1}) - 0.5}{F(x_{i+1}) - F(x_i)} + x_{i+1} \frac{0.5 - F(x_i)}{F(x_{i+1}) - F(x_i)} \quad (5)$$

where $F(x_i) = \sum_{k=1}^{i} W_k / \sum_{k=1}^{n} W_i$ and $F(x_i) \leq 0.5 < F(x_{i+1})$.

The confidence intervals (CI) for the statistical parameters were calculated by Equation (6) [23], allowing estimates of the lower (LL) and upper (UL) values for mean and median.

$$CI(\theta,\gamma) = \hat{\theta}_y \pm z_{1-\frac{\alpha}{2}} \sqrt{V_{cl}(\hat{\theta})} \quad (6)$$

where $\hat{\theta}$ is the estimator of the statistical parameter θ, $z_{1-\frac{\alpha}{2}}$ is the quantile of standard normal distribution for a confidence level of $\gamma = (1-\alpha)\%$, and V_{cl} is the estimator for variance.

In the case of interval estimates of the averages, $t_{1-\frac{\alpha}{2}}$ was used, which is Student's t distribution quantile. The variance estimates of the V_{cl} estimators were made using the collapsed strata method, given that there were strata with only one element. This method creates artificial superstrata by aggregating the existing strata, randomly or using an auxiliary variable of similarity between the strata, from which the variance of the parameter of interest is estimated. In this study, the average of the areas in each hydrographic basin was used as a measure of similarity between the strata [24].

2.3. On-Site Flow Measurement in the Selected Areas

The on-site flow (Q_{obs}) was determined from the velocity (V), which was measured by an acoustic doppler velocimeter (ADV) flow tracker in the selected reading points (Loc_i, i = 1 ... n) with 5 cm to 15 cm intervals along the watercourse section and the respective widths (L_i, i = 1 ... n) and depths (h_i, i = 1 ... n) (Figure 2, adapted from [25]). The measuring section area (A) of each watercourse was estimated by summing the subareas (A_i, i = 1 ... n), corresponding to $L_i \times h_i$, using the trapezoid method. A single measurement of the flow, made during the drought period, was adopted according to legislation in force in Goiás [26].

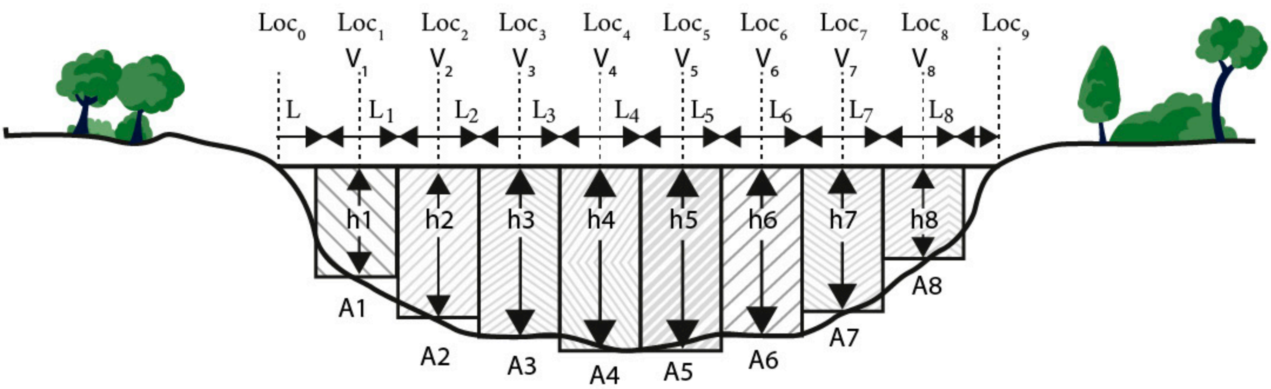


Figure 2. Schematic representation for flow measurement in selected watercourse sections. Loc: reading point, V: velocity, L: width, h: depth.

The measurement point of each watercourse was chosen considering the ease of access, straightness, and absence of rocks and branches that could interfere with the quality of the measurements. Selected measuring points were sectioned according to the schematic representation of Figure 2 for measuring V, L, and h. All measurements were performed between 22 September and 5 October 2020. This period coincides with the end of the dry season in the state and was defined by the water resources management authorities as the best for measuring minimum flows.

2.4. Comparison between Estimated and Measured Flows

After obtaining the estimated regionalized minimum flows (Q_{ref}) and the observed minimum flows (Q_{obs}), the results were compared between them and with the specific flow (Q_{spe}) of each UPGRH determined in the PERH [1]. Furthermore, the accuracy of the results was assessed from the relative error (RE) between the observed (Q_{obs}) and estimated (Q_{est} = Q_{ref} or Q_{spe}) flows through Equation (7) [21].

$$RE = \left(\frac{Qobs - Qest}{Qobs}\right) \times 100 \quad (7)$$

where RE is the relative percentage error, Q_{obs} is the flow obtained from the measurement in L/s, and Q_{est} is the flow estimated based on regionalization methods in L/s.

The mean and median are measures of the dataset centrality, in which the mean depends on all dataset values and the median is calculated based on the positions of the data. Different from the mean, the median is not sensitive to discrepant data. The confidence intervals were calculated for a 95% confidence level.

The Shapiro–Wilks hypothesis test was performed to verify whether a set of data comes from a population with normal distribution, considering the application of Student's *t*-test to compare the means. For cases in which the normality hypothesis was rejected, the Wilcoxon nonparametric test was applied, which tests the difference between medians [24].

All estimates, including the means, medians, relative errors, standard deviations (SDs), and coefficients of variation (CVs), were made using the R software with RStudio interface (version 1.3.1056) and the survey (version 4.0), srvyr (version 0.4.0), and ReGenesees (version 2.1) packages, except for the Wilcoxon test, which was applied using the GNU PSPP software (version 1.4.1-g79ad47).

To find a variable that could help in the clustering of collapsed strata and in the ratio estimates, a correlation analysis was performed for the results obtained from the application of the three methodologies (PERH (2015) [18], Honório (2020) [8], and Costa (2021) [19]) between the following variables: area (km^2), Q_{ref} (L/s), Q_{obs} (L/s), large-sized animals (number of heads), pastures (percentage of the area), agriculture (percentage of the area), forest, and non-vegetated area (percentage of the area). The number of large-sized animals in each hydrographic basin was estimated based on the Agricultural Census (2017) [27]. Land use was determined from the *MapBiomas* Project [28].

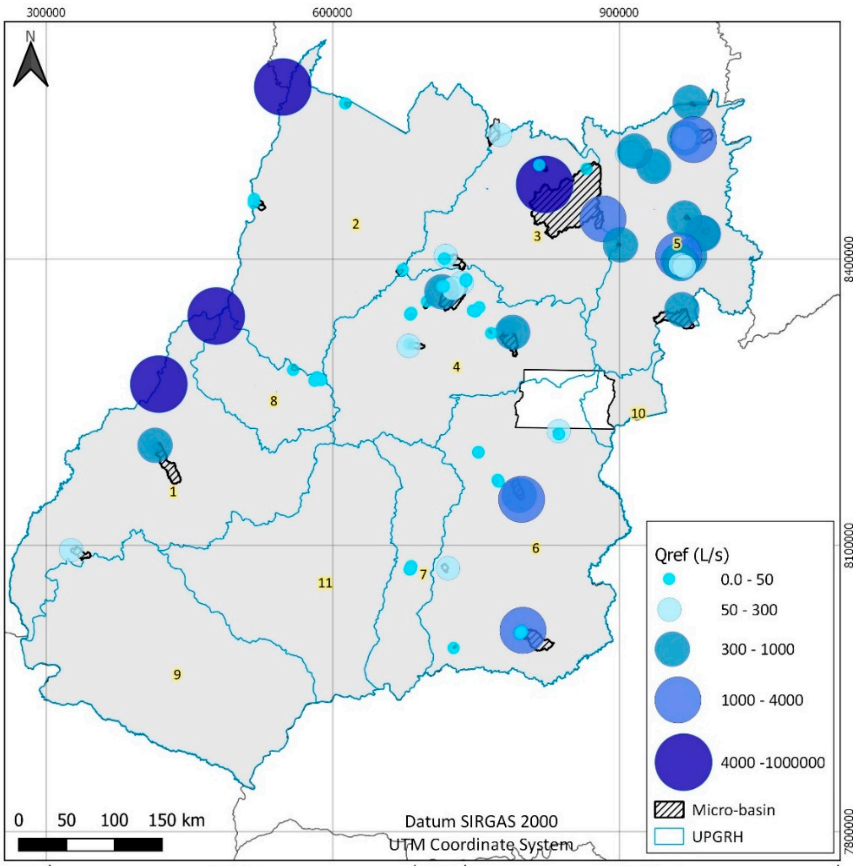
3. Results and Discussion

3.1. Minimum Reference Flow Estimate in All Hydrographic Basins

To give an idea of the Q_{ref} distribution in the state of Goiás, the values were calculated for the 92 hydrographic basins in the eleven UPGRH, using the Q_{spe} proposed by PERH (2015) [18]. Values ranged from 0.000357 to 909,109.603 L/s and are presented in Figure 3. Only eight of the eleven UPGRH are represented by the 92 hydrographic basins.

3.2. Selection of Hydrographic Basins for On-Site Sampling

The number of representative hydrographic basins (n_h) for on-site flow measurements was selected through the application of Equation (2), using the information on population variability, E = 536 and $\alpha = 0.05$. To increase the accuracy of the estimators and adapt the sample size to the available time and resources, as the reference flow had high variability and discrepant values, the study target population was divided into two subpopulations. Subpopulation 1 was composed of four basins with a probability of inclusion in the sample equal to 1, defined when considering in the sample the inclusion of the three basins with the highest flows, i.e., the "Upper Araguaia" hydrographic basin and the "Araguaia river" hydrographic basin in the UPGRH of the "Upper-Middle Araguaia". Subpopulation 2 was composed of the other basins, with a probability of inclusion in the sample lower than 1, where simple random sampling was performed without replacement in each stratum.



ID	UPGRH	ID	UPGRH
1	Alto Araguaia	6	Corumbá, Veríssimo e São Marcos
2	Médio Araguaia	7	Meia Ponte
3	Médio Tocantins	8	Vermelho
4	Almas e afl. Goianos do Maranhão	9	Baixo Paranaíba
5	Paranã e Correntes	10	Afl. Goianos do São Francisco
		11	Turvo e dos Bois

Figure 3. Reference flow range determined in the 92 hydrographic basins, distributed throughout the UPGRH in the state of Goiás, using Qspe.

The results are presented in Table 1, and it can be observed that 21 basins (n_h) in eight of the eleven UPGRH are representative of the initial 92 hydrographic basins, whose areas ranged from 123,349.55 km^2 to 0.151 km^2. Only the UPGRH of "Lower Paranaíba", "Goianos tributaries of the S. Francisco river", and "Turvo and of the Bois" are not represented. The values of strata size (N_h), the proportion of each stratum concerning the population (N_h/N), and the standard deviation (S_h) of the reference flow considering the target population are presented.

3.3. Comparative Analysis between Estimated and Observed Flows

PERH's (2015) [1] methodology allowed obtaining Q_{ref} values by multiplying the Q_{spe} by the drainage area of the 21 selected hydrographic basins. The Honório (2020) [8] and Costa (2020) [19] methodologies calculated Q_{ref} as the value of Q_{95} obtained from the application of regression equations (Equation (1)) to the drainage areas of the 21 selected hydrographic basins. PERH (2015) [18] has Q_{spe} values and Honório (2020) [8] has regression equations for the selected 21 hydrographic basins, while Costa (2020) [19] has no regression equations for application in the hydrographic basins of "Tributary of the Corrente 3 river", "Arroio Vereda Grande stream", "Tributary of the Paranã 2/Cor Morcego", "Tributary of the Paranã river 1", and "Tributary of the Paranã river 4". Results are presented in Table 2.

Table 1. N_h and S_h values and the number n_h of basins selected per hydrographic basin.

ID	UPGRH	Hydrographic Basin	Target Population			Subpopulation 2			n_h
			N_h	N_h/N	S_h	N_h	N_h/N	S_h	
1	"Upper Araguaia"	Upper Araguaia	3	0.033	202,420.25	0	0	NA	3
		Caiapó	2	0.022	157.17	2	0.02	157.17	1
2	"Upper-middle Araguaia"	Upper-middle Araguaia	4	0.043	393,656.00	3	0.03	0.0013	2
3,4	"Middle Tocantins", "Almas river and goianos tributaries of the Maranhão river"	Upper Tocantins	30	0.326	2171.25	30	0.33	2171.25	5
5	"Paranã and Correntes"	Paranã	19	0.206	709.89	19	0.21	709.89	3
		Correntes	12	0.131	341.50	12	0.13	341.50	2
6	"Corumbá, Veríssimo and São Marcos"	Corumbá	10	0.109	368.59	10	0.11	368.59	2
		São Marcos	3	0.033	494.12	3	0.03	494.12	1
7	"Meia Ponte"	Meia Ponte	4	0.043	16.41	4	0.04	16.41	1
8	"Vermelho"	Vermelho	5	0.054	14.13	5	0.05	14.13	1

On-site observed flows show a great variation throughout the 21 hydrographic basins, ranging from 0 L/s in nine hydrographic basins ("Landi stream", "Ponte Grande stream", "Tributary of the Corrente 3 river", "Arroio Vereda Grande stream", "Tributary Posse das Flores stream 1", "Tributary of the Paranã 2/Cor Morcego", "Tributary of the Paranã river 1", "Tributary of the Paranã river 4" and "Tributary of the Veríssimo river 1") to a maximum of 338.990 L/s ("Araguaia river 1"). As expected, larger flows are associated with basins with larger areas in the Araguaia river, namely, "Araguaia river 1" (71,067.5 km^2), "Araguaia river" (53,544.7 km^2), and "Araguaia river 3" (51,260 km^2), with 338,990 L/s, 171,017.6 L/s, and 185,455.9 L/s, respectively. A similar trend is observed for the flows estimated using the three methodologies.

It seems that null flows are not only associated with the sampling period, since historical data show precipitation and flows in those hydrographic basins. It is quite surprising that no flow was observed at sampling points in the hydrographic basin of "Landi stream" (51.3 km^2), "Arroio Vereda Grande stream (52.4 km^2), "Ponte Grande stream" (13.8 km^2), and "Tributary of the Veríssimo river 1" (19.4 km^2), since they have large drainage areas, higher than the ones of "Tributary of the Maranhão river", "Gameleira stream", "Cachoeirinha stream" and " Água Limpa stream", where flows were measured. Therefore, no flow was found in 42.9% of the basins, which corresponds to 51.1% of the 46 communities.

Q_{ref} estimated through the three methodologies shows no null flows for these nine hydrographic basins, although there are no results for Costa (2020) [19] in five of these hydrographic basins. For the "Landi stream", explication for null Q_{obs} is associated with an upstream water withdrawal license, which is drying the stream downflow. Thus, water withdrawal may be above Q_{95}, as there was no flow upstream. Locals are withdrawing water for uses other than house supply, violating Resolution No. 22/2019 [7], which requires reporting other water uses.

The other cases of zero Q_{obs} occurred in hydrographic basins located in the UPGRH of "Middle Tocantins ", "Paranã and Correntes", "Meia Ponte", and "Veríssimo and São Marcos", and it seems that the application of the three regionalization methodologies overestimated the minimum flow. Thus, there is a need to issue licenses for the annual period, as several streams dry up during the dry season. Silva et al. (2015) [29] concluded that the Q_{90} and Q_{95} flows were lower in the half-yearly and four-monthly periods when compared with the annual period in the Paraopeba (Minas Gerais, Brazil) river hydrographic basin.

Therefore, the application of the official methodology (PERH (2015) [18]) in Goiás can put the water viability at risk in some basins, since licenses for water withdrawal are approved based on that methodology.

Table 2. Estimated Q_{ref} using the methodologies of PERH (2015) [18], Honório (2020) [8], and Costa (2020) [19], and on-site measurements.

ID	UPGRH	Community	Hydrographic Basin	Area (km^2)	Q_{ref}, (L/s)			Measure
					Costa (2021) [19]	Honório (2020) [8]	PERH (2015) [18]	Q_{obs} (L/s)
1	"Upper Araguaia"	Pouso Alegre	Ribeirão Grande	128.4	119.0	378.5	473.8	540.1
2	"Upper Araguaia"	Itacaiú	Araguaia river 1	71,067.5	484,555.5	397,990.7	262,238.9	338,990.0
3	"Upper Araguaia"	Registro do Araguaia	Araguaia river 2	53,544.7	333,847.4	291,357.8	197,579.9	171,017.6
4	"Upper-middle Araguaia"	Landi	Landi stream	51.3	0.00356	0.00619	85.1	0.0
5	"Upper-middle Araguaia"	Fio Velasco	Araguaia river 3	123,349.6	909,109.6	535,276.9	204,760.2	185,455.9
6	"Middle Tocantins"	Queixo Dantas	Tributary of the Maranhão river	5.1	3.0	18.3	16.0	4.4
7	"Middle Tocantins"	Itajá II	Gameleira stream	5.5	3.3	19.8	17.3	21.3
8	"Middle Tocantins"	São Domingos	Cachoeirinha stream	5.6	3.34	20.0	13.1	23.1
9	"Middle Tocantins"	Engenho da Pontinha	Ponte Grande stream	13.8	8.45	48.4	43.5	0.0
10	"Middle Tocantins"	Povoado Vermelho	Macaco stream	33.3	32.9	114.0	79.3	25.5
11	"Upper Araguaia" (Caiapó)	Fortaleza	Retiro stream	16.5	8.0	4.4	473.8	3.0
12	"Paranã and Correntes"	Castelo, Retiro and Três Rios	Tributary of the Corrente 3 river	4.6	(*)	236.2	12.7	0.0
13	"Paranã and Correntes"	Castelo, Retiro and Três Rios	Arroio Vereda Grande stream	52.4	(*)	1165.5	146.2	0.0
14	"Corumbá, Veríssimo and São Marcos"	Piracanjuba	Sucuapara stream	36.5	299.9	733.1	169.8	51.2
15	"Corumbá, Veríssimo and São Marcos"	Almeidas	São Sebastião	150.8	1039.6	616.7	700.9	704.6
16	"Meia Ponte"	Rochedo	Tributary Posse das Flores stream 1	1.0	6.1	6.1	4.6	0.0
17	"Paranã and Correntes"	Pelotas	Tributary of the Paranã 2/Cor Morcego	4.9	(*)	248.6	13.8	0.0
18	"Paranã and Correntes"	Quilombo dos Magalhães	Tributary of the Paranã river 1	9.7	(*)	386.5	27.1	0.0
19	"Paranã and Correntes"	Quilombo dos Magalhães	Tributary of the Paranã river 4	0.2	(*)	25.2	0.4	0.0
20	"Corumbá, Veríssimo and São Marcos"	Madre Cristina	Tributary of the Veríssimo river 1	19.4	111.0	46.9	90.0	0.0
21	"Vermelho"	Água Limpa	Água Limpa stream	8.8	14.7	14.1	20.5	12.1

Note: (*) No regionalization equation can be fitted.

Different trends in Q_{ref} variation were noted for the three methodologies. For the bigger hydrographic basins ("Araguaia river 1", "Araguaia river 2", and "Araguaia river 3"), Costa's (2020) [19] equations largely overestimated the flows and thus do not seem suitable for application when drainage areas are over 50,000 km^2. For such cases, the Q_{spe}-based methodology of PERH (2015) [8] seems more suitable. For smaller basins, results do not allow the choice of a suitable method.

For a better understanding of trends and fittings, relative errors (RE) were calculated (Table 3) using Equation (7). Fittings are considered good when the RE is lower than 30% in module [18], indicating underestimation (positive values) or overestimation (negative values) of flows, and it can be observed in both cases for the application of the three methodologies. Costa's (2020) [19] methodology shows two results within the limit, whereas PERH's (2015) [18] and Honório's (2020) [8] methodologies show six results each, within the limit. Results on RE are according to the ones found by Araújo et al. (2018) [30] (between 0.2% and 83.8%) for the "Piquiri river" basin (Paraná, Brazil), with areas between 274.3 km^2 and 20,943 km^2, and also in the range of values from −19.1% to 62.9% found by Pruski et al. (2016) [31] for the "Corrente river" basin (34.253 km^2).

Table 3. Percentage relative error for the three methodologies.

Community	Hydrographic Basin	Area (km^2)	RE (Costa [19]) (%)	RE (Honório [8]) (%)	RE (PERH [18]) (%)
Pouso Alegre	Ribeirão Grande	128.4	77.96	29.92	12.28
Itacaiu	Araguaia River 1	71,067.50	−42.94	−17.40	22.64
Registro do Araguaia	Araguaia River 2	53,544.70	−95.21	−70.37	−15.53
Fio Velasco	Araguaia River 3	123,349.6	−390.20	−188.63	−10.41
Queixo Dantas	Tributary of Maranhão river	5.1	31.81	−316.97	−264.05
Itajá II	Gameleira stream	5.5	84.36	6.7	18.34
São Domingos	Cachoeirinha stream	5.6	85.44	13.34	42.86
Povoado Vermelho	Macaco stream	33.3	−29.36	−347.10	−211.08
Fortaleza	Retiro stream	16.5	−167.32	−46.30	−15,693.32
Piracanjuba	Sucuapara stream	36.5	−485.87	−1331.88	−231.67
Almeidas	São Sebastião	150.8	−47.55	12.47	0.52
Água Limpa Q	Água Limpa stream	8.8	−21.20	−16.89	−69.49

However, there are significant differences in RE values for the three methodologies in the hydrographic basin of the "Retiro stream", where the errors ranged from −167.32% (RE-Costa) to −15,693.32% (RE-PERH), and in the hydrographic basin of the "Sucuapara stream", where the errors ranged from −485.87% (RE-Costa) to −1331.88% (RE-Honório). In these two cases, values were overestimated concerning the observed flow, alerting against water security, as they indicate a higher amount of water than that observed through the measurements.

The use of regression equations is not recommended for regions with limits higher than the measurement station interval [31], which makes water resource management a complex and difficult task. In this research, about 38% (eight basins) of the 21 hydrographic basins are considered small, with drainage areas ranging from 0.15 km^2 to 150.75 km^2. The application of the traditional regionalization method in small drainage areas requires careful analysis due to its high heterogeneity, which makes it difficult to characterize hydrologically homogeneous regions [30]. Another issue is related to the differences in spatial and temporal scales of the rainflow transformation processes in small and large hydrographic basins.

Mean, median, and 95% confidence intervals (CI) (lower and upper limits) were calculated for Q_{obs} and Q_{ref} for the three methodologies, and RE according to Equations (3)–(6). Standard deviations and coefficients of variation were also calculated. The results are shown in Table 4 and Figure 4.

CI (LL and UL) results (Table 4) indicate a significant difference in the flow averages, as they did not intersect each other. On the other hand, all CI of the relative error averages and medians intersect each other, showing that there is no significant difference between the relative error averages. However, conclusions based on this evidence cannot be confirmed by Student's *t*-test, considering that the data normality hypothesis was rejected by the Shapiro–Wilks test (Table 5). The Shapiro–Wilks test rejects the normality of the data at a significance level lower than 1%, so the non-parametric paired Wilcoxon test was applied instead of Student's *t*-test, which has a data normality assumption.

Table 4. Mean, median, SD, and CV for Q_{obs}, Q_{ref}, and RE.

Variable	Mean (μ)			Median (M)			SD	CV
	$\hat{\mu}$	LL	UL	$\hat{M}$	LL	LS		
Q_{obs} (L/s)	7765.6	7729.3	7801.9	0.0	0.0	10.2	44,464.0	5.7
Q_{ref} (L/s) [18]	7465.5	7440.1	7490.9	20.9	13.4	85.8	40,653.8	5.4
Q_{ref} (L/s) [8]	13,815.9	13,684.1	13,947.8	48.1	19.6	379.2	76,513.5	5.5
Q_{ref} (L/s) [19]	19,273.9	19,245.1	19,302.8	8.3	3.2	125.8	139.057.2	7.2
$Q_{obs} - Q_{ref}$ (L/s) [18]	294.1	260.7	327.5	−13.8	−80.6	−2.3	8913.7	30.3
$Q_{obs} - Q_{ref}$ (L/s) [8]	−5930.6	−6333.4	−5,527.9	−47.7	−339.2	−1.9	39,558.7	−6.7
$Q_{obs} - Q_{ref}$ (L/s) [19]	−16,963.8	−19,509.7	−14,417.8	−6.6	−210.3	1.2	97,637.3	−5.8
RE (%) [18]	−61.82	−82.13	−41.51	−100.00	−100.00	−70.50	55.30	−89.45
RE (%) [8]	−66.25	−83.88	−48.61	−100.00	−100.00	−77.42	47.10	−71.10
RE (%) [19]	77.15	−56.72	211.02	−31.13	−95.85	1.58	256.00	331.81

$\hat{\mu}$: mean; LL: lower limit; UL: upper limit; $\hat{M}$: median; SD: standard deviation; CV: coefficient of variation.

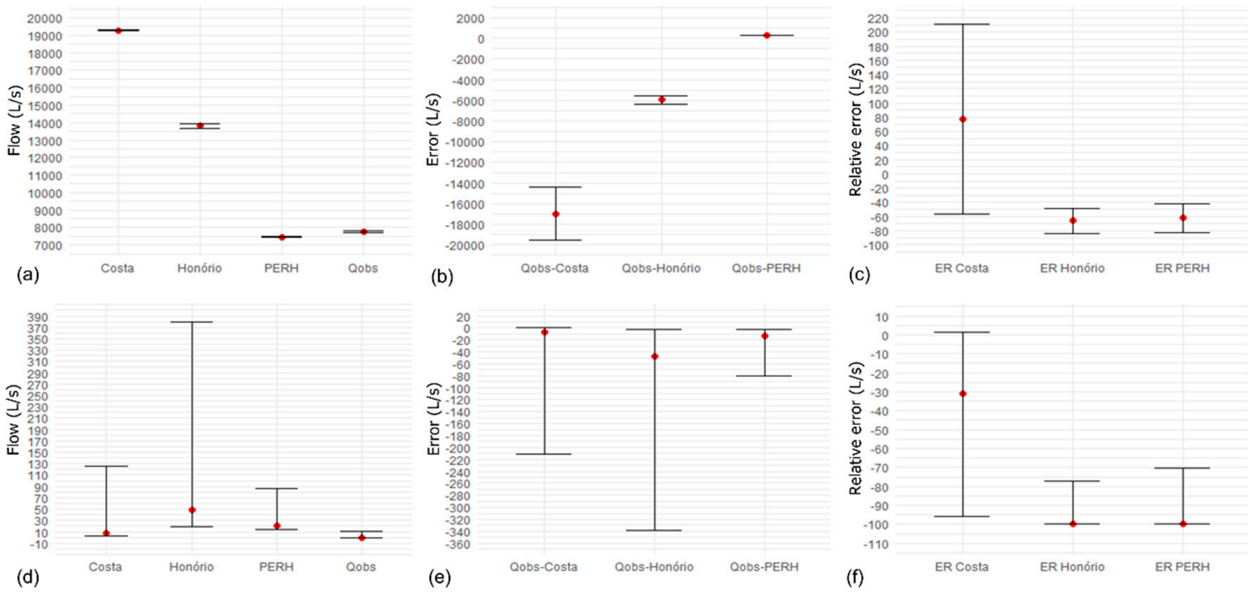


Figure 4. Confidence intervals: (**a**) mean of flows, (**b**) means of the differences between Q_{obs} and Q_{ref}, (**c**) mean of RE, (**d**) median of flows, (**e**) medians of the differences between Q_{obs} and Q_{ref}, and (**f**) median of RE.

Table 5. Results of the hypothesis tests for differences between Q_{obs} and Q_{ref}.

	Shapiro–Wilks Normality Test (*p*-Value)	Paired Wilcoxon Test (*p*-Value)
$Q_{obs} - Q_{ref}$ [18]	<0.001 *	0.002 *
$Q_{obs} - Q_{ref}$ [8]	<0.001 *	0.002 *
$Q_{obs} - Q_{ref}$ [19]	0.0074 *	0.181

Note: * Statistically significant difference at a significance level lower than or equal to 5%.

Wilcoxon tests rejected the equality of the Q_{obs} medians for the PERH [18] methodology (*p*-value = 0.002) and Honório [8] methodology (*p*-value = 0.002), with a significance level lower than 1%. For the Q_{obs} and Costa (2021) [19] medians, the hypothesis of equality of medians was not rejected (*p*-value = 0.181). It can be observed that the Q_{obs} and Costa (2021) [19] medians had a smaller difference in comparison with the other medians, but, in contrast, they had a greater difference in the averages. This can be explained due to the sensitivity of the average to discrepant values, as observed in [19].

The regression equations adapted from Honório (2020) [8] and Costa (2021) [19] for flow estimation can be applied in rural hydrographic basins of Goiás, as the relative errors are above 30% and there is evidence of significant statistical differences between means and medians. Moreover, there were also significant differences between the flow medians and the values of flows estimated from Honório's (2020) [8] equations and PERH's (2015) [18] specific flow, with a significance level lower than 1%.

Although a smaller difference has been identified between the medians calculated for the three methodologies, there is a greater difference between the average flows estimated by the Costa (2021) [19] equations and those found by the other two methodologies, due to the presence of discrepant values in the flow estimates. Both the standard deviation and the coefficient of variation values found for estimates from PERH (2015) [18] and Honório (2020) [8] are lower than those found for estimates from Costa (2021) [19], and, therefore, the two first methodologies seem to be more suitable for application in rural hydrograph basins of Goiás than the latter one.

3.4. Correlation Analysis

Correlation analysis on results obtained from the application of the three methodologies (PERH (2015) [18], Honório (2020) [8], and Costa (2021) [19]) was not possible for the data and results of Costa (2021), because this author only had regression equations for eight UPGRH, so it was not possible estimate Q_{ref} for five hydrographic basins. The different confidence limits are associated with different basin sizes covered by PERH (2015) [18], Honório (2020) [8], and Costa (2021) [18]. The correlation analysis was carried out for the methodologies that presented values for all hydrographic basins and UPGRH. Therefore, correlation analysis was only carried out for the application of PERH (2015) [18] and Honório (2020) [8] methodologies.

The correlation analysis showed two groups with significant correlations at a maximum significance level of 10% (Figure 5). In the first group, the variables area, number of large-sized animals, and flows had strong positive correlations, ranging from 0.85 to 1.00. In the second group, pasture, forest, non-vegetated areas, and agriculture had a moderate to strong negative correlation, with a coefficient ranging from −0.88 to −0.39. Due to the high correlation between the area and the estimated and observed flows, the area was thus used as an auxiliary variable in the construction of collapsed strata and the estimates by the ratio method.

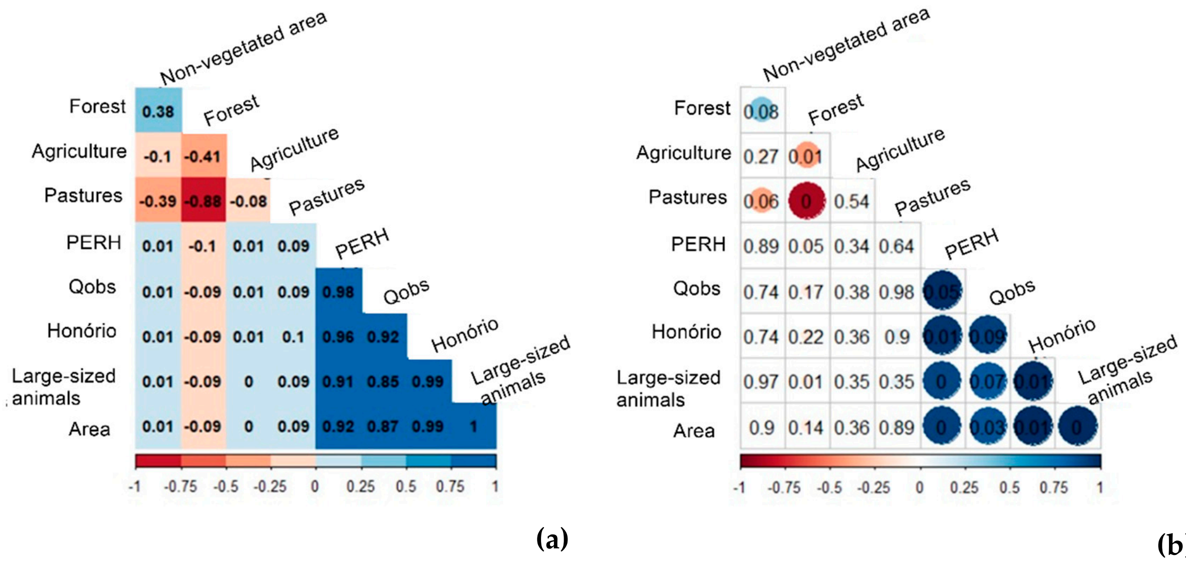


Figure 5. (**a**) Pearson correlation estimates and (**b**) *p*-values of the hypothesis tests with a null hypothesis of correlation equal to zero (PERH [18] and Honório [8] methodologies).

3.5. Water Security Analysis

The water security concept is related to the quantity and quality of water for both humans and ecosystem uses. Water security in Brazil is connected to water availability, water use, wastewater collection and treatment, and water resources management [32]. The increase in land use, especially for agriculture activities, and the effects of climate change are two major challenges for water security. The effects of climate change on water availability were evaluated in the "Ribeirão do Lobo" hydrographic basin (São Paulo, Brazil) [33] for five future scenarios, using hydrological and climatic models based on the report of the Intergovernmental Panel on Climate Change (IPCC). One of these scenarios demonstrated that the increase in air temperature and decrease in rainfall may reduce by up to 55.50%, 54.18%, and 38.17% the flows Q_{90}, $Q_{95,}$ and $Q_{7,10}$, respectively, until the end of the 21st century.

Looking at the results of this research and analyzing water security from the perspective of water quantity, the use of regionalization methods for estimating hydrographic basin flows in rural communities of Goiás showed significant errors, including the methodology of PERH (2015) [18], which adopts the specific flow per hydrographic basin and is currently used by the water management body of the state. The situation is serious in basins with low flow, as the method leads to an overestimation of Q_{ref}, which is the basis for issuing licenses for water use. Therefore, the current flow estimation methodology can put water security at risk in the state as it may generate distorted flow information.

4. Conclusions

The results of this research show that there is high variability between the minimum reference flows and the observed/measured minimum flows in the 21 hydrographic basins located in rural regions of the state of Goiás (Brazil). The regression equations proposed by Honório (2020) [8] and the specific flows provided in the PERH (2015) [18] provided satisfactory results for the analyzed basins, the PERH (2015) [18] methodology being more suitable for larger basins. For eight of the assessed hydrographic basins, no flow was observed, but all methodologies calculated available minimal flows. Therefore, the application of the official methodology (PERH (2015) [18]) can put the water security at risk in these cases in drought periods since licenses for water withdrawal are approved based on specific flows. The lack of registration of other water uses besides the licensee is another cause of low or null flows due to the over-extraction of allowed volumes. Flow regionalization is a viable methodology for estimating reference flows in rural hydrographic basins where data are not available, but the obtained results must be confirmed with field measurements because they may be over or underestimated. It is necessary to expand the monitoring network to obtain better estimates, as otherwise, it is not possible to guarantee the state's water security.

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References

1. Khan, A.; Koch, M.; Tahir, A. Impacts of climate change on the water availability, seasonality and extremes in the upper Indus basin (UIB). *Sustainability* **2020**, *12*, 1283. [CrossRef]
2. Milly, P.; Dunne, K.; Vecchia, A. Global pattern of trends in streamflow and water availability in a changing climate. *Nature* **2005**, *438*, 347–350. [CrossRef] [PubMed]
3. Kostianaia, E.; Kostianoy, A. Regional Climate Change Impact on Coastal Tourism: A Case Study for the Black Sea Coast of Russia. *Hydrology* **2021**, *8*, 133. [CrossRef]
4. *Institui a Política Nacional de Recursos Hídricos*; Law N° 9.433; Diário Oficial da República Federativa do Brasil: Brasília, Brazil, 1997. Available online: https://www.planalto.gov.br/ccivil_03/leis/l9433.htm (accessed on 5 January 2022).
5. Araújo, A.; Rocha, P. Regime de Fluxo e Alterações Hidrológicas no rio Tibagi-Bacia do rio Paranapanema/Alto Paraná. *Rev. Geogr.* **2010**, *27*, 14. Available online: https://periodicos.ufpe.br/revistas/revistageografia/article/view/228901 (accessed on 27 December 2021).
6. Granemann, A.; Mine, M.; Kaviski, E. Frequency analysis of minimum flows. *Braz. J. Water Resour.* **2018**, *23*, 1–14. [CrossRef]
7. CERHI. *Estabelece o Regulamento do Sistema de Outorga das Águas de Domínio do Estado de Goiás*; Resolution N° 22.; Conselho Estadual de Recursos Hídricos–CERHi, Diário Oficial Do Estado de Goiás: Goiânia, Brazil, 2019. Available online: https://www.meioambiente.go.gov.br/files/Resolucoes/Resol_CERHi_22_2019.pdf (accessed on 5 February 2022).
8. Honório, M. Avaliação da Disponibilidade Hídrica Superficial no Estado de Goiás. Master's Thesis, Federal University of Goiás, Goiânia, Brazil, 2020. Available online: https://repositorio.bc.ufg.br/tede/handle/tede/10601 (accessed on 3 January 2022).
9. Silva, E.; Silva, K.; Sousa, F.; Tavares, F. A escassez hídrica na zona rural: O consumo de água sob a perspectiva dos agricultores de um assentamento no município de Pombal-PB. *Res. Soc. Dev.* **2019**, *8*, 36861038. [CrossRef]
10. Akhtar, F.; Awan, U.K.; Borgemeister, C.; Tischbein, B. Coupling remote sensing and hydrological model for evaluating the impacts of climate change on streamflow in data-scarce environment. *Sustainability* **2021**, *13*, 14025. [CrossRef]
11. Xu, J.; Zhu, X.; Li, M.; Qiu, X.; Wang, D.; Xu, Z. Shifts in dry-wet climate regions over China and its related climate factors between 1960–1989 and 1990–2019. *Sustainability* **2022**, *14*, 719. [CrossRef]
12. Beskow, S.; Norton, L.; Mello, C. Hydrological prediction in a tropical watershed dominated by Oxisols using a distributed hydrological model. *Water Resour. Manag.* **2013**, *27*, 341–363. [CrossRef]
13. Javeed, Y.; Apoorva, K. Flow regionalization under limited data availability–Application of IHACRES in the Western Ghats. *Aquat. Procedia* **2015**, *4*, 933–941. [CrossRef]
14. Song, J.; Her, Y.; Suh, K.; Kang, M.; Kim, H. Regionalization of a rainfall-runoff model: Limitations and potentials. *Water* **2019**, *11*, 2257. [CrossRef]
15. Samuel, J.; Coulibaly, P.; Metcalfe, R. Estimation of continuous streamflow in Ontario ungauged basins: Comparison of regionalization methods. *J. Hydrol. Eng.* **2011**, *16*, 447–459. [CrossRef]
16. Zheng, X.; Duan, D.; Yang, L.; Wang, H. Decomposed iterative optimal power flow with automatic regionalization. *Energies* **2020**, *13*, 4987. [CrossRef]
17. Wagener, T.; Wheater, H. Parameter estimation and regionalization for continuous rainfall-runoff models including uncertainty. *J. Hydrol.* **2006**, *320*, 132–154. [CrossRef]
18. SECIMA. *Plano Estadual de Recursos Hídricos do Estado de Goiás (PERH/GO), Produto 5*; Secretaria de Estado de Meio Ambiente, Recursos Hídricos, Infraestrutura, Cidades e Assuntos Metropolitanos: Goiânia, Brazil, 2015; 290p. Available online: https://www.meioambiente.go.gov.br/images/imagens_migradas/upload/arquivos/2016-01/p05_plano_estadual_de_recursos_hidricos_revfinal2016.pdf (accessed on 3 January 2022).
19. Costa, I. Disponibilidade Hídrica Superficial e Subterrânea de Assentamentos em Goiás. Master's Thesis, Federal University of Goiás, Goiânia, Brazil, 2021.
20. Eletrobrás. *Manual de Minicentrais Hidrelétricas*; Centrais Elétricas Brasileiras, S.A. Ministério das Minas e Energia: Rio de Janeiro, Brazil, 1985; p. 354.
21. Cochran, W. *Sampling Techniques*; John Wiley and Sons: New York, NY, USA, 1977; p. 442.
22. Horvitz, D.; Thompson, D. A generalization of Sampling without Replacement from a Finite Universe. *J. Am. Stat. Assoc.* **1952**, *47*, 663–685. Available online: https://www.stat.cmu.edu/~{}brian/905-2008/papers/Horvitz-Thompson-1952-jasa.pdf (accessed on 23 December 2021). [CrossRef]
23. Sarndal, C.; Swensson, B.; Wretman, J. *Model Assisted Survey Sampling*; Springer: New York, NY, USA, 1992; 695p. Available online: https://link.springer.com/book/9780387406206 (accessed on 28 December 2021).
24. Rust, K.; Kalton, G. Strategies for Collapsing Strata for Variance Estimation. *J. Off. Stat.* **1987**, *3*, 69–81. Available online: https://www.scb.se/contentassets/ca21efb41fee47d293bbee5bf7be7fb3/strategies-for-collapsing-strata-for-variance-estimation.pdf (accessed on 28 December 2021).
25. SonTek. *FlowTracker Handheld ADV Technical Manual*; YSI, Inc.: San Diego, CA, USA, 2007; 126p. Available online: https://www.uvm.edu/bwrl/lab_docs/manuals/Flow_Tracker_Manual.pdf (accessed on 29 December 2021).
26. *Estabelece O Regulamento Do Sistema de Outorga Das Águas de Domínio Do Estado de Goiás*; Resolution n° 09.; Secretaria de Estado de Meio Ambiente e Desenvolvimento Sustentável, Diário Oficial do Estado de Goiás: Goiânia, Brazil, 2005. Available

online: http://www.sgc.goias.gov.br/upload/arquivos/2015-10/resolucao-ndeg09_04-de-maio-de-2005.pdf (accessed on 22 December 2021).
27. IBGE. *Censo Agropecuário 2017*; Instituto Brasileiro de Geografia e Estatística: Rio de Janeiro, Brazil, 2017. Available online: https://censos.ibge.gov.br/agro/2017/ (accessed on 22 December 2021).
28. Souza, C., Jr.; Shimbo, J.; Rosa, M.; Parente, L.; Alencar, A.; Rudorff, B.; Hasenack, H.; Matsumoto, M.; Ferreira, L.; Souza-Filho, P.; et al. Reconstructing three decadesof land use and land cover changes in Brazilian biomes with landsat archive and earth engine. *Remote Sens.* **2020**, *12*, 2735. [CrossRef]
29. Silva, B.; Silva, D.; Moreira, M. Influência da sazonalidade das vazões nos critérios de outorga de uso da água: Estudo de caso da bacia do rio Paraopeba. *Rev. Ambiente E Água* **2015**, *10*, 623–634. [CrossRef]
30. Araújo, F.; Mello, E.; Gollin, G.; Quadros, L.; Gomes, B. Streamflow regionalization in Piquiri river basin. *Eng. Agrícola* **2018**, *38*, 22–31. [CrossRef]
31. Pruski, F.; Rodriguez, R.; Pruski, P.; Nunes, A.; Rego, F. Extrapolation of regionalization equations for long-term average flow. *Eng. Agrícola Jaboticabal* **2016**, *36*, 830–838. [CrossRef]
32. Santos, A.; Reis, A.; Mendiondo, E. Segurança hídrica no Brasil: Situação atual, principais desafios e perspectivas futuras. *Rev. DAE* **2020**, *68*, 167–179. [CrossRef]
33. Neves, G.; Barbosa, M.; Anjinho, P.; Thomassim, T.; Filho, J.; Mauad, F. Evaluation of the impacts of climate change on streamflow through hydrological simulation and under downscaling scenarios: Case study in a watershed in southeastern Brazil. *Environ. Monit. Assess.* **2020**, *192*, 707. [CrossRef] [PubMed]