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Effectiveness of Water Producer projects: case study of the Water Producer project in the Camboriú river Basin, Santa Catarina - Brazil

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Abstract - The Brazilian National Water Agency ("ANA"), created a strategy to help solve the problem of water shortage in Brazil, named the Water Producer Program (WPP). The main objective of this project is to increase the quantity and quality of water in key water basins. In the present study, we propose a protocol model to measure the effectiveness of water supply projects in Brazil. The protocol was applied as a case study in the water producer (WP) project of the Camboriú River Basin (BHRC), in the state of Santa Catarina, Brazil. The indicators used to develop the protocol were adherence of landowners; conservation and restoration areas; adequately maintained roads; hydrological monitoring; environmental education; project management; and water quality and quantity. Results showed a 50% effectiveness of the protocol applied to the WP project of the BHRC, which can be considered a good value, considering the relatively recent development of the project, going back four years. The protocol created for this study can aid WP project managers in Brazil by providing an adaptable methodology to measure effectiveness over time.

Key words: Monitoring. Quality Indicators. Protocol. Payment for Environmental Services.

Eficácia de projetos produtores de água: estudo de caso do projeto Produtor de Água na Bacia Hidrográfica do Rio Camboriú, Santa Catarina - Brasil

Resumo - A Agência Nacional de Águas (ANA) desenvolveu uma estratégia para colaborar na resolução do problema de falta de água no Brasil, o Programa Produtor de Água (PPA). Este tem como principal meta o aumento da quantidade e qualidade da água nas bacias hidrográficas estratégicas. O presente trabalho tem como objetivo foi propor um modelo de protocolo para mensurar a eficácia dos projetos Produtores de Água no Brasil. O protocolo foi aplicado como estudo de caso no Projeto Produtor de Água (PA) da Bacia Hidrográfica do Rio Camboriú (BHRC), estado de Santa Catarina, SC. Os indicadores utilizados no desenvolvimento do protocolo foram: adesão dos proprietários rurais; áreas de conservação e restauração; estradas devidamente adequadas; monitoramento hidrológico; educação ambiental; gestão do projeto; qualidade e quantidade de água. A partir da aplicação do protocolo no projeto Produtor de Água da BHRC o resultado demonstrou uma eficácia de 50%, valor que pode ser considerado bom, devido ao curto tempo de desenvolvimento do projeto, quatro anos. O protocolo desenvolvido pode contribuir com os gestores dos projetos Produtores de Água no Brasil, apresentando metodologia adaptável para mensurar sua eficácia ao longo do tempo.

Palavras-chave: Monitoramento. Indicadores de Qualidade. Protocolo. Pagamento por Serviços Ambientais.

Efectividad de proyectos productores de agua: estudio de caso del Proyecto de Producción de Agua en la Cuenca del Río Camboriú, Santa Catarina – Brasil

Resumen - La Agencia Nacional del Agua (ANA) desarrolló una estrategia para ayudar a resolver el problema de la escasez de agua en Brasil, el Programa Productor de Agua (PPA). El objetivo principal de esto es aumentar la cantidad y calidad del agua en cuencas hidrográficas estratégicas. El presente trabajo tiene como objetivo proponer un modelo de protocolo para medir la efectividad de los proyectos de Productores de Agua en Brasil. El protocolo fue aplicado como estudio de caso en el Proyecto Productor de Agua (PA) de la Cuenca del Río Camboriú (BHRC), estado de Santa Catarina, SC. Los indicadores utilizados en el desarrollo del protocolo fueron: adhesión de propietarios rurales; áreas de conservación y restauración; carreteras mantenidas debidamente; monitoreo hidrológico; educación ambiental; gestión de proyectos; calidad y cantidad de agua. De la aplicación del protocolo en el proyecto BHRC Water Producer, el resultado arrojó una eficiencia del 50%, un valor que puede ser considerado bueno, debido al corto tiempo de desarrollo del proyecto, cuatro años. El protocolo creado para este estudio puede ayudar a los gerentes de proyectos de AP en Brasil, al proporcionar una metodología adaptable para medir la efectividad a lo largo del tiempo.

Palabras clave: Seguimiento. Indicadores de calidad. Protocolo. Pago por servicios ambientales.

Introduction

Water is an essential natural resource for the survival of almost all species that inhabit the planet. Data from the United Nations Children's Fund - UNICEF - and the World Health Organization – WHO, for the period 2000-2015, show that almost half of the world's population does not have a basic sanitation service (Barbosa 2015). The demand for water resources is largely influenced by population growth through urbanization policies, macroeconomic processes and others (Abreu and Tontello 2017, Silva and Schwingel 2021). Water contamination due to different types of pollutants, such as fertilizers, sewers, heavy metals, or pesticides, is a major problem in Brazil and all over the world. Furthermore, growing urbanization and industrialization generate a range of diffuse sources of contamination that compromise the quality of water resources (Tundisi and Tundisi 2008).

The Brazilian Ministry of the Environment (MMA) created the National Water Agency (ANA) in accordance with Law 9.984 of 2000, to fulfill the objectives of the Water Law in Brazil. The ANA focuses on the following lines of action: (a) regulation of access to and use of government-owned water resources; (b) monitoring of the status of water resources through the national hydrometeorological network; (c) compliance with laws by overseeing implementation of the National Water Resources Policy (PNRH, *Política Nacional de Recursos Hídricos*, in Portuguese), creating and supporting programs and projects, management bodies, and the establishment of watershed management committees and agencies; and (d) planning by creating and participating in strategic studies together with public institutions and bodies (ANA 2018).

ANA, in partnership with other institutions, has been developing the water producer program (WPP) to improve, recover, and protect water resources in strategic hydrographic basins. This program is based on actions carried out in rural areas to reduce erosion and the silting of springs

and, consequently, increase the quality and regularity of water supplies (ANA 2008). The WPP uses payment for environmental services (PES) as a way of encouraging landowners to voluntarily adopt water and soil conservation practices. PES is a public policy initially created in Costa Rica as a mechanism to reduce significant environmental degradation in the country (Starzynski and Simões 2015, Santos 2012).

In the last 15 years, the concept of PES has been used in several experiences to maintain the quality and quantity of water resources in Brazil, as in the case of the conservation project in Extrema and the eco-credit program in Montes Claro, both in the state of Minas Gerais-Brazil, and the oasis project in the springs of the metropolitan region of São Paulo - Brazil, among others (ANA 2012). In the state of Santa Catarina-Brazil, three ongoing projects are the environmental management program of regional water sources - SOS Springs (*Programa de Gestão Ambiental da Região dos Mananciais – SOS Nascentes,* in Portuguese), municipality of Joinville; the Municipal Quiriri Consortium, municipalities of São Bento do Sul, Rio Negrinho, Corupá, and Campo Alegre, and the water producer (WP) project in the Camboriú River Basin (BHRC), municipalities of Balneário Camboriú and Camboriú (MMA 2011). According to the Brazilian Ministry of the Environment (2011), many of these projects and programs are incipient and do not comply with their objectives because they are not monitored appropriately.

Also according to the MMA, PES projects and programs need monitoring, which is often non-existent, because they do not comply with the proposed objectives, thus placing their credibility in doubt. Moreover, it is necessary to establish efficiency indicators for water producer programs that would, in turn, support the implementation of this conservation strategy in different Brazilian river basins. Therefore, studies that define indicators and assess the success of WP projects are fundamental to justify continued public and private investments in this conservation strategy and the implementation of new projects.

Inspired by the WPP of the ANA and by international experiences, the municipal water and Sanitation Company of Balneário Camboriú (EMASA, *Empresa Municipal de Água e Saneamento de Balneário Camboriú*, in Portuguese) created the water producer (WP) project at the BHRC. This initiative was established by Municipal Law 3.026, of 26 November 2009 (CVBC 2018) to develop instruments that ensure the conservation of water resources in the Camboriú River Basin and encourage landowners to adopt conservationist practices in their properties. These practices involve the restoration of degraded areas, the conservation of native forest remnants and rural roads, and effective soil management to increase the quality and quantity of water in the BHRC (Wegner et al. 2011) .

Consequently, the aim of this study was to create and implement a protocol to measure the effectiveness of water producer projects, based on the case study of the water producer project of the Camboriú River Basin (SC) developed with landowners since 2013.

Material and methods

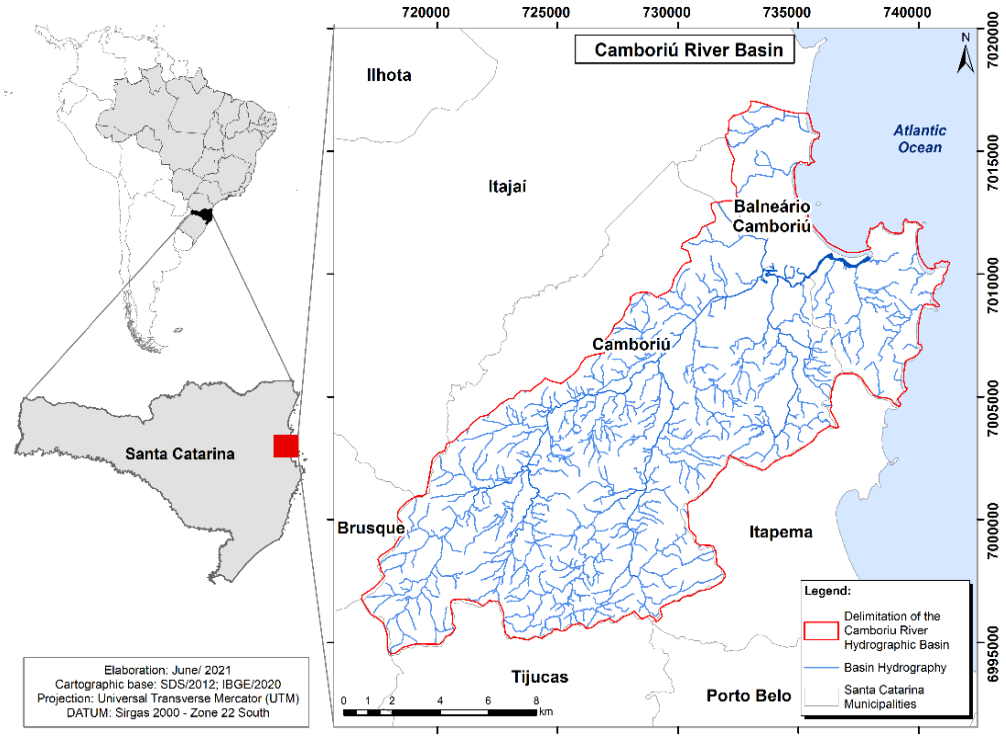
Study area

The study object of this work is the Camboriú River Basin (BHRC) on the north-central coast of the state of Santa Catarina - Brazil, between latitudes 27°2'0"S and 27°8'0"S and longitudes 48°40'0"W and 48°48'0"W (Figure 1). The BHRC drains an area of approximately 200 km^2; its main

river, the Camboriú, is around 40 km long and crosses the municipalities of Balneário Camboriú and Camboriú. Around 90% of the springs that make up the Camboriú River Basin are in the municipality of Camboriú (Antunes et al. 2007).

The relief of the basin is characterized by two units: Serra do Tabuleiro, which is a mountain range, and coastal plains. The Serra do Tabuleiro is characterized by steep slopes and deep valleys with sedimentary silt-clay deposits and quartz sand, with their peculiar characteristics, thus favoring the process of erosion and landslides in deforested areas (Urban 2008). The main rivers that make up the Camboriú River Basin are Ribeirão dos Macacos and rivers do Salto, do Braço, and Pequeno (Antunes et al. 2017). BHRC suffers environmental pressure from several economic sectors, especially irrigated agriculture, fish and pay, and mining in the upper (upstream) portion and real estate, civil construction and tourism in river mouth (downstream) portion.

Figure 1. Location of the Camboriú River Basin - Brazil.



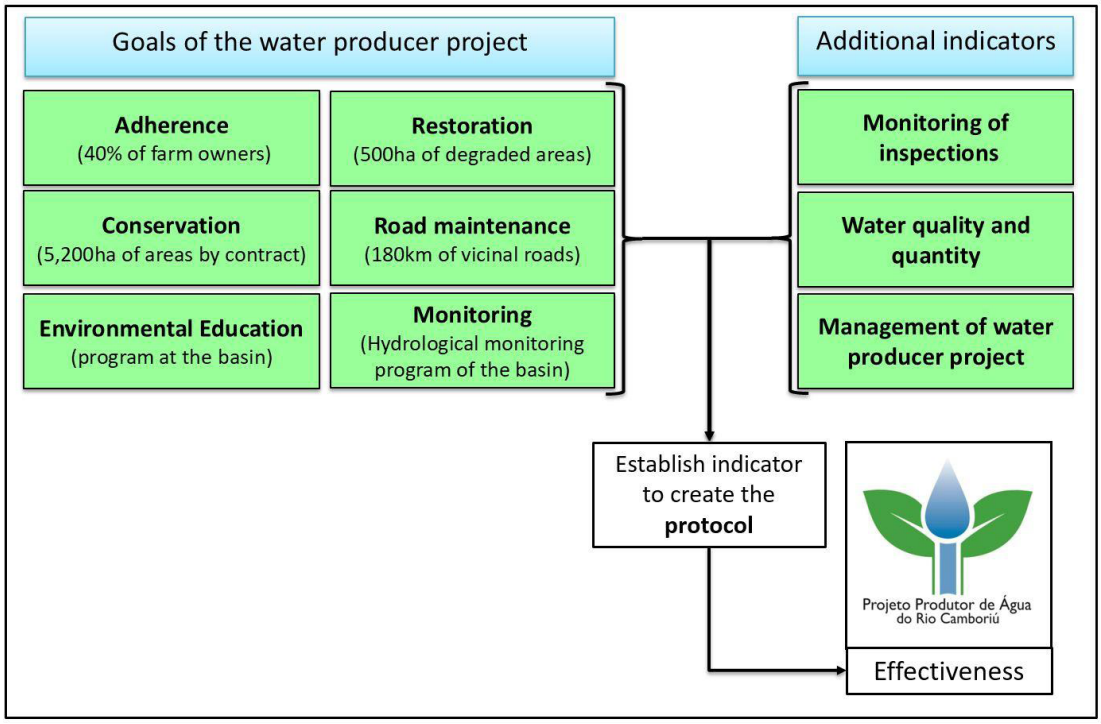
The intervention area of the WP project, located upstream of the BHRC, was initially 138 km2 (Dacol 2011), which corresponds to around 70% of the entire basin area. The chosen pilot area was the Braço River Sub-Basin, for the first stage of the project. In 2016, EMASA, based on the second the Public Notice, expanded the operation area of the project to the Ribeirão dos Macacos Sub-Basin, for the second stage of the project. The third stage of the project comprises implementation in the Pequeno River Sub-Basin, although the date has not been defined (EMASA 2016).

Methodological Procedures

In the present study, a protocol was created and applied to measure the effectiveness of the WP project using indicators based on the criteria of Lustosa (1999). The selected indicators were

adherence of at least 40% of the landowners; 500 ha of degraded areas in the process of restoration, prioritizing riparian forests; 5200 ha of conservation areas protected by landowners, by contract; 180 km of adequately maintained vicinal roads; implementation of the water monitoring plan of the basin; and implementation of the environmental education program, all of which are the goals of the WP project. These indicators are goals of the WP project and the data was provided by Water and Sanitation Company (EMASA). Additional indicators were also considered by the authors of the present study, i.e. water quality; water quantity; monitoring of the WP project; and management of the WP project. Figure 2 shows a flow chart with the indicators.

Figure 2. Flow chart of indicators constructed to measure the effectiveness of the water producer project in the Camboriú River Basin - Brazil.



The methodology applied to analyze the indicators adherence, restoration, conservation, and adequate roads was the ratio (%) between the predictive target and the value realized by the WP project each year that compose annual and cumulative effectiveness (general). Since the WP project aims to achieve the targets by the year 2035 (PSA 2017) and the first adherence was in 2013, it was determined that the time to reach the targets will be 23 years. For the indicator monitoring (inspection) of the WP project (Santos and Schwingel 2017), the following four parameters were established: inspection interval, team, quality, and report. Each parameter was given a score of 10 (excellent), 7 (good), 4 (fair) or zero (bad). The indicator environmental education was also given a score of 10 (present, with annual programming); 7 (present,with occasional actions only); 4 (present, with specific actions only); or zero (not present with no actions). The hydrological monitoring plan was established through the ratio (%) between the ideal number and the observed number of stations. For management of the WP project, the following four parameters were established: number and frequency of manager meetings, participation in inspection, and vehicle used for inspection. Each

parameter was given a score of 10, 7, 4, or zero, according to its specificities. For the indicator water quality, the following eleven parameters were established: dissolved oxygen, hydrogenionic potential, turbidity, conductivity, biochemical demand for oxygen, ammonium, nitrate, phosphate, nitrite, silica, and chlorophyll. Each parameter received a score of 10 (improved), 7 (maintained), 4 (reduced by up to 50%), or zero (reduced by more than 50%). The indicator water quantity was given a score of 10 (increased), 7 (maintained), 4 (reduced by 50%), or zero (reduced by more than 50%). This indicator was based on the average flow values (m3s-1) measured by EPAGRI (2017) at two sampling points in the period from 2012 to 2017. Overall effectiveness was defined by the sum of the analyses of each indicator, with its corresponding weights, according to the importance of each indicator in the water producer project.

Results and discussion

Indicator - Adherence

The goal of the WP project for the indicator adherence is 40% of the properties of the BHRC in 2013. In all, 298 properties in the basin can potentially adhere to the project, so the target is 119 properties. The number of properties divided by the duration of the project (23 years) results in the yearly total of properties that adhered to the project. Interestingly, the target was reached in 2014 and 2016 but not in the remaining years, so the effectiveness of this indicator was 66% (Table 1). To reach the goals, more investments must be made to divulge the project and show landowners the importance and benefits of adherence to the project (Santos and Schwingel 2019).

Table 1. Indicator adherence to the water producer project of the Camboriú River Basin - Brazil.

Year	Number of adhered rural properties							
	Goal		Input	Output	Balance		Effectiveness %	
	Annual	Accumu.*			Annual	Accumu.*	Annual	General
2013	5.2	5.2	5	2	3	3	58	58
2014	5.2	10.4	6		6	9	116	87
2015	5.2	15.6	6		6	15	116	96
2016	5.2	20.8	1		1	16	19	77
2017	5.2	26.0	2	1	1	17	19	66
.								
2035	5.2	119.6						

* Accumulated

Indicator - Restoration

The goal of the WP project for the indicator restoration is 500 ha in 23 years, corresponding to 21.74 ha/year. Data analysis showed that the target was only reached in 2014, with 125%, and the restored areas were below expectations in the remaining years, therefore, effectiveness of this indicator was 36% (Table 2). The low adherence of landowners to the WP project may be one of the reasons for the ineffectiveness of this indicator.

Table 2. Indicator restoration area/ha of the water producer project of the Camboriú River Basin - Brazil.

Year	Restoration area/ha							
	Goal		Input	Output	Balance		Effectiveness %	
	Annual	Accum.*			Annual	Accum*	Annual	General
2013	21.7	21.7	11.90	10.74	1.17	1.17	5	5
2014	21.7	43.4	27.28		27.28	28.45	125	65
2015	21.7	65.1	0.85		0.85	29.29	4	45
2016	21.7	86.8	0.00		0.00	29.29	0	34
2017	21.7	108.5	9.81		09.81	39.11	0	36
.								
2035	21.7	500.0						

* Accumulated

Indicator - Conservation

The goal of the WP project for the indicator conservation is 5,200 ha in 23 years, which corresponds to 226 ha/year. Data analysis revealed that the goal was only reached in 2014 (107%), and the restored areas were below expectations in the remaining years; therefore, the effectiveness of this indicator is 46% (Table 3). This indicator is of paramount importance because the conservation of forest areas inside and outside the permanent protection area (APP - Área *de Proteção Permanente,* in Portuguese) contributes to different processes, such as the infiltration of rainwater into the soil and the retention of nutrients, without which bodies of water can become eutrophicated (EMPRAPA 2003).

Table 3. Indicator conservation area/ha of the water producer project of the Camboriú River Basin - Brazil.

Year	Conservation areas/ha							
	Goal		Input	Output	Balance		Effectiveness %	
	Annual	Accum.*			Annual	Accum.*	Annual	General
2013	226	226	64.34	2.06	62.28	62.28	28	28
2014	226	452	241.32		241.32	303.60	107	67
2015	226	678	76.47		76.47	380.08	34	56
2016	226	904	121.40		121.40	501.48	54	55
2017	226	1,130	14.13		14.13	515.61	6	46
.								
2035	226	5,200						

* Accumulated

Indicator - Adequately maintained roads

The goal of the WP project for maintenance was 180 km of roads in 23 years, corresponding to 8 km/year. The assessment results of this indicator showed that, until 2017, the goal was not reached and 5.2 km of roads were adapted only in 2015 through the basin containment project (FUCAM 2017), thus representing an effectiveness of 13% (Table 4). The low effectiveness of this result is due to the lack of investment of the local government of Camboriú in road improvements and maintenance.

Table 4. Indicator rural roads (Km) with interventions of the water producer project to improve drainage of the Camboriú River Basin - Brazil.

Year	Adequately maintained roads (km)						
	Goal		Completed	Balance		Effectiveness %	
	Annual	Accum.*		Annual	Accum.*	Annual	General
2013	8	8	0.0	0.0	0.0	0	0
2014	8	16	0.0	0.0	0.0	0	0
2015	8	23	5.2	5.2	5.2	66	22
2016	8	31	0.0	0.0	5.2	0	17
2017	8	39	0.0	0.0	5.2	0	13
.							
2035	8	180					

* Accumulated

Indicator - Monitoring (inspection) of the WP project

For monitoring, the parameters interval, team, quality, and report of inspection were analyzed. The parameter interval between each inspection showed an effectiveness of 60.0% obtained after analysis of the variation of each interval from 20 September 2013 to 15 December 2017 (Table 5).

The inspection team continued with the same members for the entire period, that is, the Camboriú Committee, FUCAM (Camboriú Environment Foundation), TNC (The Nature Conservancy), and SEMAN (Secretary of the Environment of Balneário Camboriú), configured as experienced and assigned a score of 7. With regard to quality of inspection, the score was 10, as the inspection team uses a follow-up checklist (Santos and Schwingel 2017), resulting in 100% effectiveness for this parameter. For the parameter inspection report, the assigned score was 10. The report used by the managers contains basic information, a checklist, and a space for the opinion of the inspection team, thus representing an effectiveness of 100%. The arithmetic mean of the analyzed parameters, which make up the indicator monitoring, obtained 82.5% for effectiveness (Table 5).

Table 5. Analysis 3. Analysis of parameters of the indicator monitoring for the water producer project of the Camboriú River Basin – Brazil..

Assessment of inspection					
Parameter	Score 10 Excellent	Score 7 Good	Score 4 Fair	Score 0 Bad	Effectiveness
Interval	6 months ± 1 week	6 months ± 2 weeks	6 months ± 3 weeks	6 months ± 4 weeks	60%
Team	Very experienced	Experienced	Minimally experienced	Not experienced	70%
Quality	Talk with property owner				100%
	Photographic record				
	Project site inspection				
	Checklist				
Reports	Introduction of the water producer project				100%
	Details of owner and property				
	Details of inspection team				
	Photographic record				
	Signature				
	Remarks				
	Checklist				
	Team opinion				
Effectiveness of the indicator monitoring (inspection)					82.5%
Very experienced (all participated in at least five inspections). Experienced (two members participated in at least two inspections). Minimally experienced (one member participated in at least one inspection). Not experienced (none of the members participated in inspection).					

Indicator - Environmental education in the water producer project

According to Wegner et al. 2011, a WP project must consider global issues that are interrelated and dependent on each other, and the conservation, restoration, and financial incentives should be presented together with a social proposal that supports environmental education policies. The main objective of the indicator environmental education is to measure the effectiveness of implementing an environmental education program at the BHRC. This indicator was given a score of 4 (40% effectiveness), as no environmental education program was created for the WP project at the BHRC. In contrast, targeted actions were performed with the community of the BHRC (Table 6).

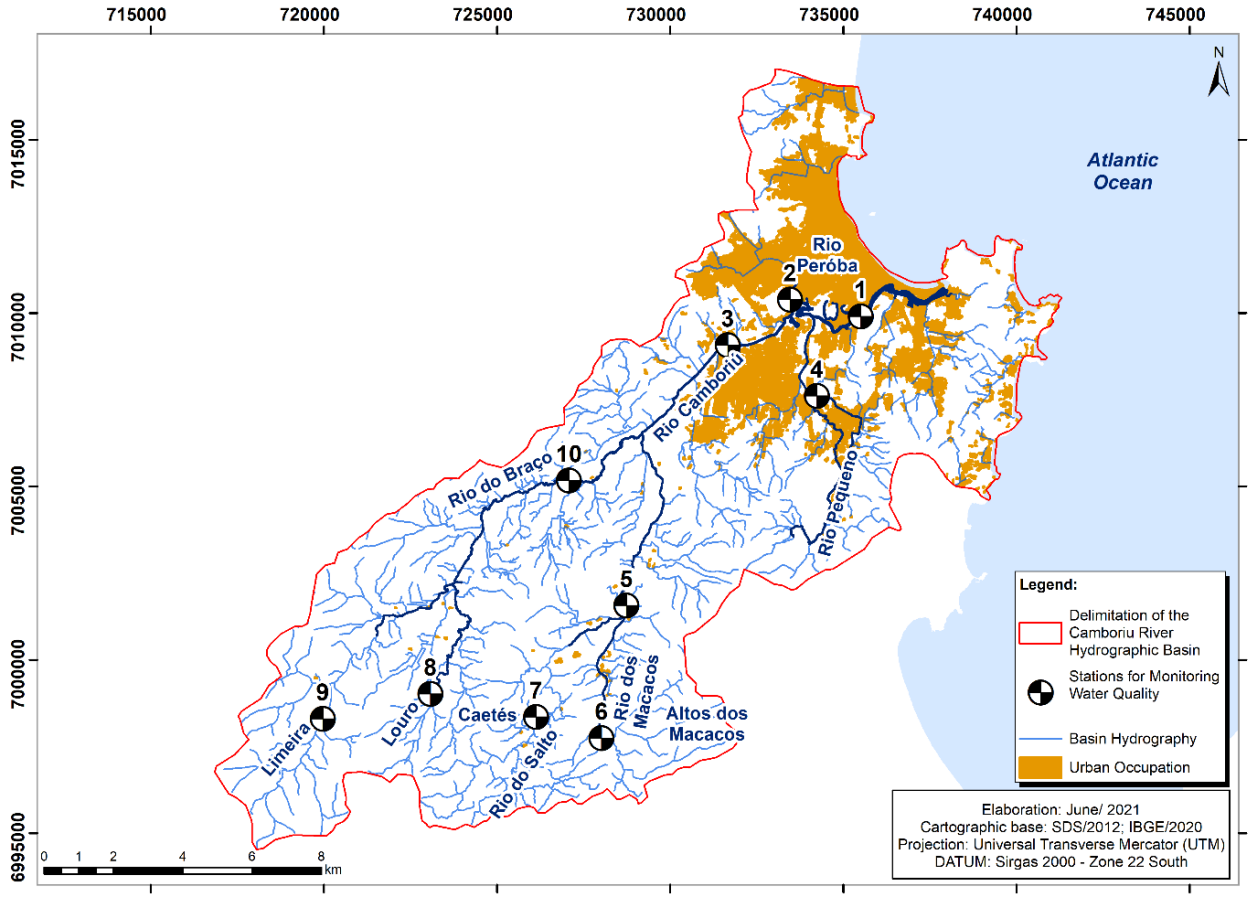
Table 6. Analysis criteria of the indicator environmental education in the Camboriú River Basin - Brazil.

Environmental education program	Score 10	Score 7	Score 4	Score 0	Effectiveness
	Present, with an annual schedule	Present, but only with targeted actions	Not present, with targeted actions	Not present, without actions	40%

Indicator - Hydrological monitoring plan

The BHRC has two main streams formed by the rivers Braços and Canoas, and the meeting of these rivers forms the Camboriú River. Five hydrometeorological stations would be needed to monitor the WP, at the beginning (Limeira and Macacos) and in the middle (Braço and Canoas) of the main streams, as well as at the EMASA catchment unit, representing points 3, 5, 9 and 10, respectively (Figure 3). However, of the five stations mentioned, only one, the EMASA catchment unit, is in operation. Lack of maintenance and investments have caused the other stations to cease operations. Thus, this indicator has an effectiveness of 20% since only one of the five monitoring stations is in operation.

Figure 3. Location of the Camboriú River Basin - Brazil, with the stations required for monitoring water quality.



Indicator - Management of the water producer project

The indicator management of the WP project is assessed to measure the quantitative form in which the project is managed, including participation of institutions in inspection and manager meetings. According to the minutes of the management group, 18 meetings were held between 2012 and 2017, with an average of 3 meetings per year, resulting in a score of 7 (70% effectiveness). Attendance of the institutions at the manager meetings was 100% for EMASA; 79% for TNC, SEMAM, and FUCAM; 57% for the Camboriú Committee and ANA; 29% for AGESAM; 14% for EPAGRI; and 0% for IFC and IDEA. The arithmetic mean of attendance of the institutions was 60% on the basis of the established criteria, which corresponds to a score of 7 (70% effectiveness) (Table 7).

Analysis of the inspection reports from 1 to 45 showed that 64% of the institutions participated in the inspections, leading to a score of 7 (70% effectiveness). The grantor provides transport to the properties for the members who participate in inspections. The vehicle used in the inspections was given a score of 4 (40% efficiency) because it was uncomfortable and unsuitable for rural roads. Effectiveness of the indicator management of the WP project was 62.5%, calculated on the basis of the arithmetic mean of the scores assigned to the evaluated criteria (Table 7).

Table 7. Analysis criteria of the indicator management of the water producer project of the Camboriú River Basin - Brazil.

Criteria	Score 10	Score 7	Score 4	Score 0	Effectiveness
No. of management group meetings/year	More than 3	3	2	1	70%
Attendance of management group meetings	> 75 %	< 75% and > 50%	< 50% and > 25%	< 25 %	70%
Participation in at least 3 inspections (1-45)	> 75 %	< 75% and > 50%	< 50% and > 25%	< 25 %	70%
Vehicle for property inspections	Comfort and suitable for rural roads.	No comfort, but suitable for rural roads.	No comfort, but accesses most rural roads.	No comfort and unsuitable for rural roads.	40%
Effectiveness of indicator management of water producer project of the BHRC					62.5%

Indicator - Water quality

The indicator water quality was assessed considering the period prior to the WP project for the data of Urban (2003; 2008) and, later, for Silva (2015) and Rabelo (2018) (Tables 8 and 9). Dissolved oxygen showed an improvement in quality in point 3 (score 10, 100% effectiveness), a decline in quality in point 5 (score 4, 40% effectiveness), and relatively constant quality levels in point 10 (score 7, 70% effectiveness). For pH, a slight improvement was recorded in all the assessed points, resulting in a score of 10 (100% effectiveness). Turbidity was assessed as stable

for the sample points 3, 5, and 10, and given a score of 7 (70% effectiveness). Conductivity showed a decline in point 3 of over 50% (score 0) and remained constant in points 5 and 10 (score 7, 70% effectiveness). The high conductivity values in point 3 can be explained by the influence of brackish water, while the high values in points 5 and 10 can be explained by the use of fertilizers in the rice crops. This increase in conductivity was verified by Conejo and Pereira Filho (2010), who found that water quality deteriorates when water is used in irrigated rice cultivation. For BOD, an improvement was recorded in point 5 (score 10, 100% effectiveness) (Table 10).

Table 8. Mean values of dissolved oxygen (DO) [mg.L-1], temperature [°C], pH, turbidity [NTU], conductivity [mS/cm], and biochemical oxygen demand (BOD) [mg.L-1] recorded by Urban (2003; 2008), Silva (2015), and Rabelo (2018) for points 3, 5, and 10 in Camboriú River Basin - Brazil.

Point	Sampling point 3		Sampling point 5		Sampling point 10	
	Before WP	After WP	Before WP	After WP	Before WP	After WP
Source / Parameter	Urban (2008)	Silva (2015) Rabelo (2018)	Urban (2003; 2008)	Silva (2015) Rabelo (2018)	Urban (2003; 2008)	Silva (2015) Rabelo (2018)
DO	4.69	5.14	6.79	5.99	6.95	6.85
Temperature	22.6	22.7	22.0	22.5	22.5	21.3
pH	6.49	6.67	6.62	6.84	6.57	6.97
Turbidity	45.15	46.73	17.46	15.53	19.77	21.28
Conductivity	0.200	0.310	0.088	0.083	0.070	0.063

Analyses of the chemical and biological parameters (Table 9) of the BHRC showed that ammonium reduced quality by over 50%, resulting in a score of 0 (0% effectiveness), and remained constant in points 5 and 10, resulting in a score of 7 (70% effectiveness). The chemical parameters nitrate, nitrite, phosphate, and silica showed a reduced concentration in points 3, 5, and 10, indicating an improvement in water quality and resulting in a score of 10 (100% effectiveness). The parameter chlorophyll-a showed a reduction in all the analyzed points, also indicating an improvement in quality and resulting in a score of 10 (100% effectiveness). The scores assigned to each parameter are listed in Table 10. Effectiveness of the indicator water quality was 83.9% (Table 10). Overall, it is observed that the WP project may have contributed to water quality in the BHRC, although the project has only recently been implemented.

Table 9. Ammonium [mg/L], nitrate [mg/L], nitrite [mg/L], phosphate [mg/L], silica [mg/L], and chlorophyll-a [mg/L] recorded by Urban (before WP, 2003; 2008) and Rabelo (after PA; 2018) in points 3, 5, and 10 of the Camboriú River Basin - Brazil.

Point	Sampling point 3		Sampling point 5		Sampling point 10	
	Before WP		After WP		Before WP	
Source Parameter	Urban (2008)	Rabelo (2018)	Urban (2003; 2008)	Rabelo (2018)	Urban (2003; 2008)	Rabelo (2018)
Ammonium	0.9157	1.3758	0.2062	0.2100	0.1466	0.1427
Nitrate	0.6366	0.2106	0.3089	0.2150	0.4658	0.2004
Nitrite	0.0395	0.0206	0.0107	0.0055	0.0114	0.0045
Phosphate	0.1500	0.0239	0.1033	0.0095	0.0445	0.0023
Silica	2.5748	2.4177	2.9363	2.4463	2.6052	1.7679
Chlorophyll-a	3.6826	1.8793	2.0160	1.0751	1.9976	1.0652

Table 10. Water quality scores for the water producer project of the Camboriú River Basin - Brazil, for sampling points 3, 5, and 10. Legend: Score 10 = Improved; 7 = Maintained; 4 = Decline < 50%; 0 = Decline > 50%

Score	Sampling point 3				Sampling point 5				Sampling point 10			
Parameter	10	7	4	0	10	7	4	0	10	7	4	0
DO	x				-	-	-	-		x		
pH	x				x				x			
Turbidity		x				x				x		
Conductivity				x		x				x		
BOD			x		-				-	-	-	-
Ammonium				x	x					x		
Nitrate	x				x				x			
Nitrite	x				x				x			
Phosphate	x				x				x			
Silica	x				x				x			
Chlorophyll	x				x				x			
Overall effectiveness of parameters												83.9%

Indicator - Water quantity

Flow data of rivers Canoas and Camboriú were collected by EPAGRI for the Canoas hydrological stations (Point 5) and the EMASA catchment unit (Point 3) (Figure 3). With regard to the flow of the Camboriú River in point 3, it is observed that the water volume increased from 2014 to 2016 (Figure 4). In 2017, a reduction in the flow was observed, possibly due to the drought season between July and September in the region. In relation to point 5 (Figure 5), the flow of the Canoas River decreases from 2012 to 2014 and increases between 2014 and 2016.

Figure 4. Flow (m^3s-1) in point 3 (Camboriú River) in the Camboriú River Basin - Brazil, from 2012 to 2017. Note: data of 2012 and 2013 not available.

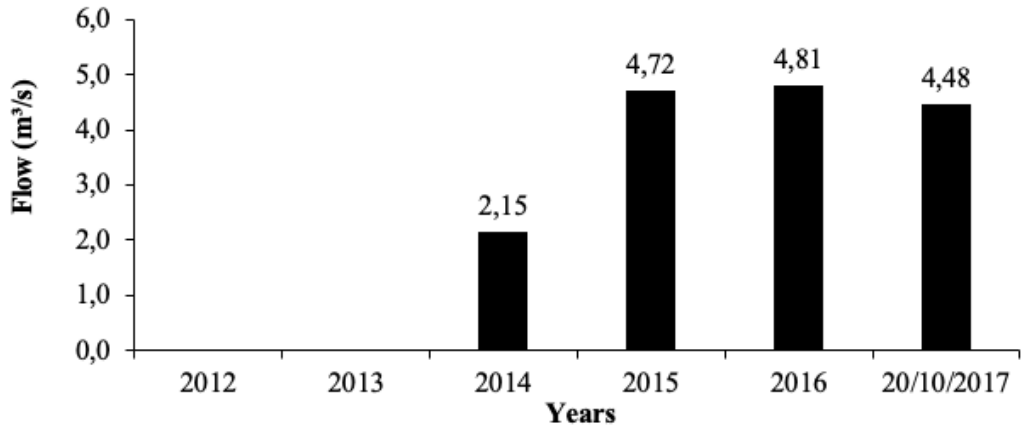
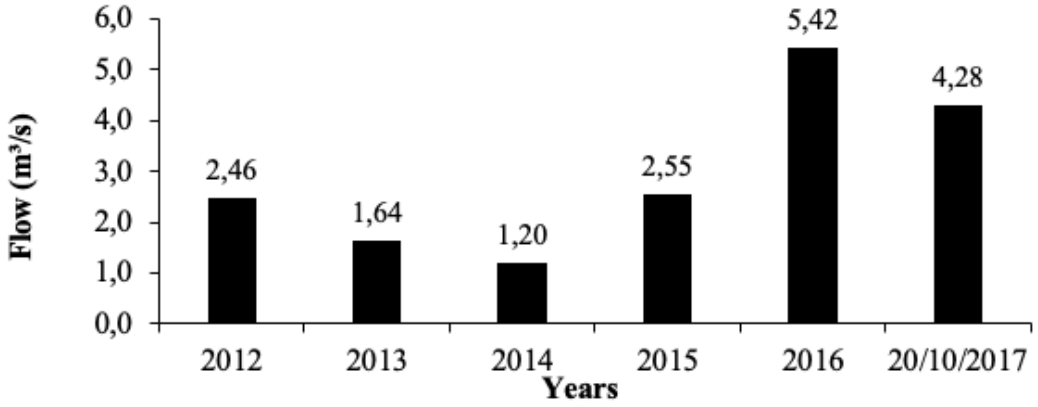


Figure 5. Flow (m^3s-1) in point 5 (Camboriú River) in the Camboriú River Basin - Brazil, from 2012 to 2017.



Flow analysis of points 3 and 5 showed an increase in flow from 2014; however, this trend of increase cannot be attributed exclusively to the WP project since its activities were only initiated with the rural producers in March 2013. Future studies can better evaluate the relationship between increased flow and the WP project. The WP project, however, may be contributing to the regularization of the flow of Camboriú River and its tributaries, thus leading to a score of 10 for this indicator, which corresponds to 100% effectiveness (Table 11).

Table 11. Analysis criteria of the indicator water quantity of the water producer project of the Camboriú River Basin - Brazil.

Parameters	Score 10	Score 7	Score 4	Score 0	Effectiveness
Flow of rivers Canoas and Camboriú	Increased	Maintained	Reduced by up to 50%	Reduced more than 50%	100%

Result of the application of the protocol to evaluate the water producer project

The protocol to evaluate the water producer project was created on the basis of indicators that were individually assigned a weight according to their importance in the WP project of the BHRC. The indicators with the highest weights were, respectively, restoration, adherence, adequate roads, conservation, and project and management monitoring. The other indicators have equal weights because they are the results of the actions developed in the water producer project of the BHRC (Table 12).

Table 12. Criteria adopted to create the effectiveness protocol of the water producer project of the Camboriú River Basin - Brazil.

Indicator	Description of indicators	Weight	Effectiveness	
			%	Real
1	Adherence of at least 40% of the landowners of the basin;	0.15	65.6	9.8
2	500 ha of degraded areas undergoing a process of restoration, with priority given to riparian forests;	0.20	36.0	7.2
3	5,200 ha of conserved areas protected by the landowners by contract;	0.10	45.6	4.6
4	180 km of adequately maintained vicinal roads;	0.15	13.3	2.0
5	Monitoring of the WP project;	0.10	82.5	8.3
6	Implementation of water monitoring plan of the basin;	0.05	20.0	1.0
7	Implementation of environmental education program in the basin;	0.05	40.0	2.0
8	Management WP project;	0.10	62.5	6.3
9	Water quality;	0.05	83.9	4.2
10	Water quantity.	0.05	100.0	5.0
Overall effectiveness of the water producer project of the Camboriú River Basin				**50.3%**

The 50.3% effectiveness result in 2017 indicates that the WP project of the BHRC has challenges to overcome and requires some adjustments to improve performance. Moreover, greater involvement of partner institutions and project promotion activities that target landowners, among other actions, can increase project performance. In the case of the WP project of the BHRC, the managers have been promoting the project since the last half of 2017, which led to an increase in the number of adhered property owners. The increase in the number of people interested in participating in the WP project enables the fulfillment of goals and increases its effectiveness. As a result of these activities, the number of adhered properties increased from 17 to 21 in June 2018, the conservation area increased from 515 ha to 1034 ha, and the restoration area increased from 39 ha to 60 ha (EMASA 2018). Effectiveness of the water producer project of the BHRC increased from 50.3% in 2017 to 56.6% in June 2018, representing a 12.5% increase in effectiveness.

Conclusion

Application of a protocol to assess the effectiveness of the WP project, based on a case study in the Camboriú River Basin, state of Santa Catarina - Brazil, revealed that the project obtained an effectiveness of approximately 50%, which can be considered a good result since the project has only recently been implemented. Because of its unprecedented nature, the protocol to measure the effectiveness of these projects and programs can be adjusted according to the situation to which it is applied. Furthermore, mid- and long-term evaluations can attest to the reliability of the protocol. Water producer projects in Brazil can apply the protocol every two years to support managers in decision making associated with the development of these programs.

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