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Assessing the Potential for Rainwater Harvesting Use in a Concentrated Animal Feeding Operation Region in the South of Brazil

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Abstract: Sustainability in intensive animal production is directly linked to water management. The increasing pressure on water resources and the occurrence of increasingly frequent and severe droughts makes it harder to meet the demand for animal husbandry in rural properties and highlights the importance of rational water use and the search for alternative sources of water supply. In the midwest region of Santa Catarina state, south of Brazil, the use of cisterns to store rainwater collected from the roofs of houses that confine animals is an alternative already widely used and encouraged to minimize water scarcity. Studies that deal with the potential for rainwater use in livestock production are still scarce; however, available information provides a concrete basis for further technical and economic feasibility studies. The present study aimed to evaluate, based on local precipitation and available harvesting areas, the potential of the use of rainwater to supply the water demand (**r**, %) and the water-saving potential (**R**, m^3/year) in swine and poultry Concentrated Animal Feeding Operations (CAFOs) in Jacutinga river basin and contiguous sub-basin municipalities, a region with great national importance in this activity. As a result, potential **r** values of 100% to supply water demand in the poultry sector and between 32.7% and 68.3% in the different production stages of the swine sector were obtained. The potential **R** value in the study area represented 5.2 million m^3 per year. Such results reveal the high potential of rainwater harvesting systems not only for minimizing impacts of drought periods but also as an abundant source of water for supplying the husbandry water demand of rural farms, ensuring water security, and serving as a tool for managing local water resources.

Keywords: concentrated animal feeding operations; water security; rainwater harvesting systems; swine; poultry

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1. Introduction

Water is a vital element and is essential for almost all economic activities. Regarding Concentrated Animal Feeding Operations (CAFOs), water presents substantial value due to the daily demand, considering animals' consumption of drinking water, the cleaning of housing buildings, and thermal comfort in nebulization [1].

In this sense, the water demand for CAFOs impacts water bills, even more so when those operations are located in regions with a high concentration of animals [2]. The high consumption of water associated with a lack of programs for its management have reduced its availability, making obvious and critical the need to use this resource in a rational way [3]. The adoption of measures to improve the efficiency of water use in agricultural activities—while guaranteeing access to water for vulnerable groups, such as small farmers—is inextricably linked to several of the Sustainable Development Goals (SDGs) listed in the 2030 Agenda of the United Nations. Among those which stand out are the following: SDG 2—zero hunger and sustainable agriculture; SDG 6—drinking water and sanitation; SDG 12—responsible consumption and production; and SDG 13—action against global climate change [2].

In Brazil, it was estimated that animal consumption corresponds to 11.6% of the total 34 billion m^3 of water consumed per year in the country, more than the industry (9.5%) and urban supply (9.1%) [4]. CAFO farms are located mainly in the south of the country, with the states of Santa Catarina, Paraná, and Rio Grande do Sul being responsible for 64.4% of the 13,245 million tons of poultry meat produced and for 68.9% of the 3,983 million tons of pork produced. In addition, they were responsible for 83.7% and 94.2% of poultry meat and pork exports, respectively [5].

Even within the aforementioned states, animal farms are located in certain regions, generating significant pressure on local water resources. The Jacutinga river basin and contiguous basins (composed of 19 municipalities), located in the midwest of Santa Catarina state, are good examples of this. Regarding the animal density in the state, this river basin concentrates about 20% of all poultry and pork production, corresponding to an area of 4% of Santa Catarina's territory [6].

The greatest difficulty in supplying water to CAFO farms is found in the spatialization of the production units, where farms are very dispersed in rural/remote areas, and the water supply networks (public water systems), in most cases, have no reach. In this sense, and to solve that scarcity, CAFO producers provide alternative water supply sources such as springs and deep wells. The significant increase in the drilling of wells in the municipalities of the Jacutinga river basin and contiguous basins has, in some cases, led to the over-exploitation of the local aquifer, causing the depletion of available water and causing groundwater pollution (Comassetto et al., 2014) [7]. In addition, there is increasing water demand in specific locations from CAFOs, making demand more local, and consequently, requiring bigger water sources with higher supply potential, which are more difficult to obtain [8].

In Brazil, specifically in Santa Catarina, an option that has appeared in recent years as a way to ensure water security for CAFOs is the installation of rooftop rainwater harvesting systems (RWHSs). In 2017, 193 RWHSs were identified by the Jacutinga River Basin and Contiguous Basins Management Committee in the municipalities within its scope, with over 70% of cisterns being installed using government subsidies and financing [8].

In order to increase and encourage the implementation of RWHSs, Santa Catarina state, through Decree-Law No. 14.675/2009 (Art. 118), started to require the installation of these systems as a prerequisite to obtain the environmental license for activities that use water resources, as is the case for CAFOs [9]. Additionally, the tendency to decrease the volume available and the quality of water resources and an increase in the cyclical periods of drought in the south of Brazil were important factors that motivated the dissemination of RWHSs in CAFOs. It was noticed that, in critical periods of drought, producers who do not have good sources and who have not adopted the use of cisterns remain dependent on municipal support by water trucks that, in general, provide low-quality water [8].

Historically, the midwest of Santa Catarina presents good average annual precipitation levels, well distributed throughout the year, which are crucial factors to the use of rainwater. One more detail is the extensive number of roofs in CAFOs, which are excellent harvesting areas to collect large volumes of water at a low cost [8,10]. CAFOs, in this context, can be considered by decision makers as a tool for water management, helping the preservation of surface and underground sources, and also being guaranteed reserves for periods of drought [3].

Since there is an information vacuum in the literature assessing the potential for RWHS use in CAFOs, studies like this can assist in the decision making of rural producers as to the installation of systems and the management of water. Furthermore, based on local results, it will be possible to subsidize the development of public policies and governmental programs to encourage accession to this technology. In this context, the present study aimed to determine the potential use of RWHSs in CAFOs (swine and poultry) as a source to supply water demand, in the municipalities located in the region of the Jacutinga River Basin and Contiguous Basins Management Committee, in the midwest of Santa Catarina. The potential of rooftop RWHSs was also assessed in terms of their ability to meet the demand for CAFO farms and the potential volume of water that could be saved from other sources at the municipal and basin level.

2. Methodology

2.1. Regionalization of Precipitation Index in Jacutinga River Basin and Contiguous Basins

The average precipitation levels for each municipality were obtained from the historical standardized series, over 42 years (1977–2018), considering the monthly precipitation of four pluviometric stations located in the study area. The study included the entire surface area of the 19 municipalities in the region of the Jacutinga River Basin and Contiguous Basins Management Committee. The historical data series was obtained from the Hidroweb—National Water Agency (ANA) platform—Brazil (Brasil, 2019b). To correct possible gaps and errors, the regional weighting method was used (Tucci, 2007) [11]. Table 1 shows the identification of the pluviometric stations used in the study, particularly with regard to the code, name, municipality, responsible entity, and their geographical coordinates.

Table 1. Identification of the pluviometric stations.

Code	Municipality Station	Responsible	Latitude	Longitude	Height
2651001	Vargem Bonita	ANA *	−26°52′24′′	−51°47′47′′	1000 m
2752005	Concórdia	ANA	−27°18′52′′	−51°59′36′′	600 m
2652001	Ipumirim	ANA	−26°57′09′′	−52°10′57′′	600 m
2751011	Irani	ANA	−27°03′04′′	−51°54′44′′	1040 m

* National Water Agency—Brazil; Source: Brasil (2019b) [12].

In order to define the average annual precipitation for each municipality, the average rainfall obtained in each data series used was distributed throughout the study area. For this, the Thiessen Polygon method was used [11]. In the municipalities that are influenced by more than one pluviometric station, a weighted average calculation was carried out concerning the municipality's area of influence in each station. Figure 1 exhibits the result of the Thiessen Polygon method application with the delimitation of the influence area of the four pluviometric stations used to obtain the average precipitation.

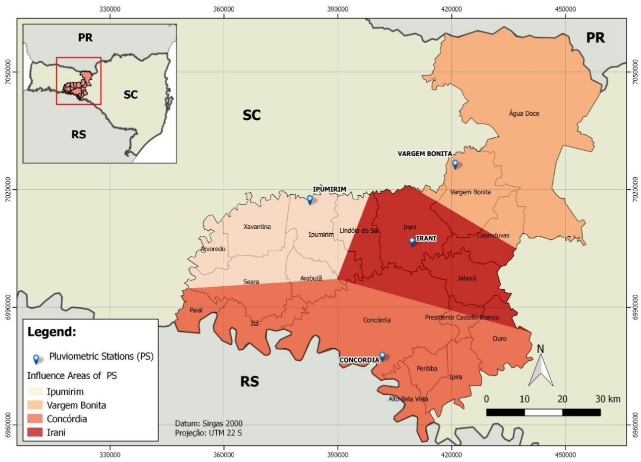

Figure 1. Delimitation area of its influence in the study area of the four pluviometric stations used—Thiessen Polygon method.

2.2. Determination of the Rainwater Volume Available for Harvesting (V_a)

The rainwater volume available for harvesting ($\mathbf{V_a}$, m^3) was determined for each municipality in the region of the Jacutinga River Basin and Contiguous Basins Management Committee, based on Equation (1):

$$V_a = A \times (P/1000) \times (E_1 \times E_2) \quad (1)$$

where **A** is the roof area available for harvesting (m^2); **P** is the average annual precipitation (mm); $\mathbf{E_1}$ is the coefficient for the system collection efficiency; and $\mathbf{E_2}$ is the coefficient for the intermediate system efficiency (disposal of the first flows and filters). Currently, the most-used roof type in farms in the region of the Jacutinga River Basin and Contiguous Basins Management Committee is fiber cement. The coefficient for the system collection efficiency (E_1) adopted was 0.90 [8,10]. Regarding the coefficient for the intermediate system efficiency (E_2), the value of 0.90 was adopted, reaching a value near to 0.80 as a product of the two efficiency coefficients, as indicated in the literature [13].

As it was not possible to obtain data on the built-up area of the CAFOs, the roof area available for harvesting (**A**) was determined by multiplying the number of animals housed in the municipality for each productive category by their respective technical coefficient of density in animal housing. Table 2 shows the effective animal herd obtained from the annual municipal livestock production report [6].

Table 2. Effective animal herd per municipality.

Municipality	Swine		Poultry	
	Total	Sows	Total	Layers
Água Doce	97,600	8900	1,946,500	4200
Alto Bela Vista	28,474	1400	374,916	3800
Arabutã	112,068	5030	2,465,227	90,800
Arvoredo	71,325	2247	710,378	4500
Catanduvas	7400	623	1,025,100	268,000
Concórdia	407,566	28,608	3,398,900	435,380
Ipira	18,407	1586	1,014,171	5500
Ipumirim	93,367	5135	3,142,893	5500
Irani	105,487	11,350	497,800	4700
Itá	106,262	7650	1,824,070	10,500
Jaborá	105,600	4055	1,152,100	42,300
Lindóia do Sul	111,934	3353	886,871	4200
Ouro	51,150	3508	3,320,400	11,300
Paial	21,440	95	410,140	3700
Peritiba	23,340	1981	228,989	4100
Presidente Castello Branco	51,229	1150	317,998	2400
Seara	257,222	31,400	2,377,990	30,000
Vargem Bonita	9817	645	1,297,450	5650
Xavantina	188,602	25,962	735,368	70,000
Total	1,868,290	144,678	27,127,261	1,006,530

Source: Brazil (2018) [6].

It was assumed that all sows belong to the productive category: breeding sows. The rest of the swine herd was divided between the categories of piglets and growing–finishing pigs, proportionally to the period of the lots, considering that the entire cycle took place in the same municipality. The piglets (42 days per lot) and growing–finishing pigs (105 days per lot) ratio was 1:2.25. In the same framework, it was also assumed that the poultry herd was divided between the categories of layers and broilers, considering each municipality, for the rest of the flock. Table 3 presents the categories of CAFOs adopted and their respective technical coefficient of density in animal housing.

Table 3. Technical coefficient of density in animal housing for each category of the concentrated animal feeding operation farms adopted.

Productive Category	Animal Housing Density (m^2/animal)
Swine: breeding sows	2.60 [1]
Swine: piglets	0.35 [1]
Swine: growing–finishing	1.15 [1]
Poultry: layers	0.12 [2]
Poultry: broilers	0.08 [3]

[1] [14]; [2] [15]; [3] [16].

Thus, it was possible to calculate the rainwater volume available for harvesting ($\mathbf{V_a}$, m^3) for each category of animal production in each municipality and the total volume available for harvesting in CAFOs in the study area, from the total of all $\mathbf{V_a}$.

2.3. Determination of the Water Demand in CAFOs—Swine and Poultry (V_d)

The water volume demand for each productive category was determined considering: (1) the daily values of animal water consumption; (2) the daily values for cleaning activities and the thermal comfort of the animal housed; (3) the cycle period per productive category; and (4) the number of cycles per year. Table 4 shows the data used for the determination of the water volume demand for each CAFO category.

Table 4. Data used to determine the water volume demand for each productive category.

Productive Category	Animal Water Consumption (L/animal/day)	Cleaning and Thermal Comfort Consumption (L/animal/day)	Cycle Period (days/cycle)	Number of Cycles (cycles/year)
Swine: breeding sows	27.8 [1]	6.0 [5]	+365	1
Swine: piglets	2.5 [1]	0.2 [6]	42 [1]	7.4
Swine: growing–finishing	8.3 [1,2]	0.6 [7]	105 [1,2,7]	3.3
Poultry: layers	0.23 [4]	0.04 [3*]	+365	1
Poultry: broilers	0.24 [3]	0.04 [3]	42 [3]	6.5

[1] [17]; [2] [18]; [3] [19]; [4] [20]; [5] [21]; [6] [22]; [7] [23]; * adopted as broilers data.

The majority of the swine and poultry CAFOs operate in Santa Catarina state over a predetermined number of lots (cycles). The daily water volume demand for each productive category was determined by multiplying the number of the days that animals remained housed in farms (each cycle) by the daily water consumption associated with these animals (drinking, cleaning, and thermal comfort activities). Sanitary breaks between lots (cycles) were assumed to be 7 days for swine and 14 days for poultry.

The annual water volume required ($\mathbf{V_d}$, m^3/year) was determined for each productive category in CAFOs, based on Equation (2):

$$V_d = ((d_1 + d_2) \times C_1 \times n \times N)/1000 \tag{2}$$

where $\mathbf{d_1}$ is the animal water consumption demand (L/animal/day); $\mathbf{d_2}$ is the water demand for cleaning and thermal comfort (L/animal/day); $\mathbf{C_1}$ is the cycle period (days/cycle); $\mathbf{n}$ is the number of cycles per year (cycles/year); and $\mathbf{N}$ is the number of animals per category.

2.4. Potential of Rooftop RWHSs at CAFOs

The potential of RWHSs to supply the water demand of CAFOs was determined for each animal production category—swine and poultry—considering the 19 municipalities located in the region of the Jacutinga River Basin and Contiguous Basins Management Committee. Overflows and evaporations were not considered; the reasons for this include the large capacity of the cistern utilized in the study area, an average of 500 m^3 [10]; their complete closure; and the occurrence of well-distributed rainfall during the year in the region of the study area. The percentage of CAFO water demand that can be supplied by RWHSs was determined based on Equation (3).

$$r = (V_a/V_d) \times 100 \quad (3)$$

where **r** is the potential of water demand that can be supplied by rainwater in CAFOs (%), $\mathbf{V_a}$ is the volume of rainwater available for use (m^3), and $\mathbf{V_d}$ is the water demand in the CAFO category (m^3). The **r** value was obtained for each CAFO animal category in each municipality.

The water-saving potential—**R**—(m^3/year) using the RWHS in a CAFO was obtained for swine and poultry categories in each municipality, based on Equation (4). The total potential of each municipality is given by the total of the R values of each animal category in the area ($\sum$R).

$$R = \mathbf{r} \times \mathbf{V_d} \quad (4)$$

The R value was also linked to the unit area, obtaining an estimation of the potential for the use of RWHSs in CAFOs per km^2, from the ratio between R and the territory area of the municipalities. The urban area of Concórdia was subtracted from the total area in the determinations given that it is a municipality with an urban area greater than 5 km^2. For the other municipalities, the total area was considered.

3. Results and Discussion

Considering the distribution performed using the Thiessen Polygon method, the annual average precipitation obtained for the 19 municipalities was 1963 mm, with a standard deviation of 41 mm. The lowest averages were determined in the municipalities with the strongest influence of the Concórdia pluviometric station: Alto Bela Vista, Ipira, Itá, Paial, and Peritiba, with an annual average of 1913 mm. The highest averages were found in the municipalities with the strongest influence of the Irani pluviometric station: Irani and Jaborá with an annual average of 2035 mm. These results obtained are in accordance with values referred to in the literature, since the annual rainfall averages in Brazil range from 1146 to 2182 mm [24], depending on the region of the country [25].

The annual rainfall distribution also showed similarity between the four stations with averages greater than 120 mm in all months (Figure 2), which are essential for the continuous use of rainwater throughout the year [8,10].

October showed the highest average rainfall, with around 220 mm. However, between March and August, the averages obtained were less than 160 mm, meaning it is important to be careful when managing collected rainfall during this period. In this respect, one option might be the use of cisterns with large storage capacities to balance the monthly rainfall variations over the year.

As previously stated, the rainwater volume available for harvesting (V_a) was determined considering the average annual precipitation obtained for each municipality, and then according to Equation (3), compared with the water demand volume (V_d) to obtain the potential supply (r) of RWHSs of CAFOs per productive category. Table 5 summarizes the results for the potential supply of the CAFO demand by RWHSs.

For swine, the water volume demand (V_d) in CAFOs was greater than the water volume available to be captured on the roofs of the farms (V_a). In addition, the potential of water demand that can be supplied (r) in this sector varied considerably according to the productive category, reaching an average of 65.9% in piglet units. As for the production of breeding sows, the potential identified was the lowest (33.5%), which is related to the higher water consumption of the animals in this productive phase, comprising adult sows and piglets not yet weaned, and the fact that this production phase is continuous. The standard deviation due to the variation of precipitation in the study area was only 1% in swine CAFOs.

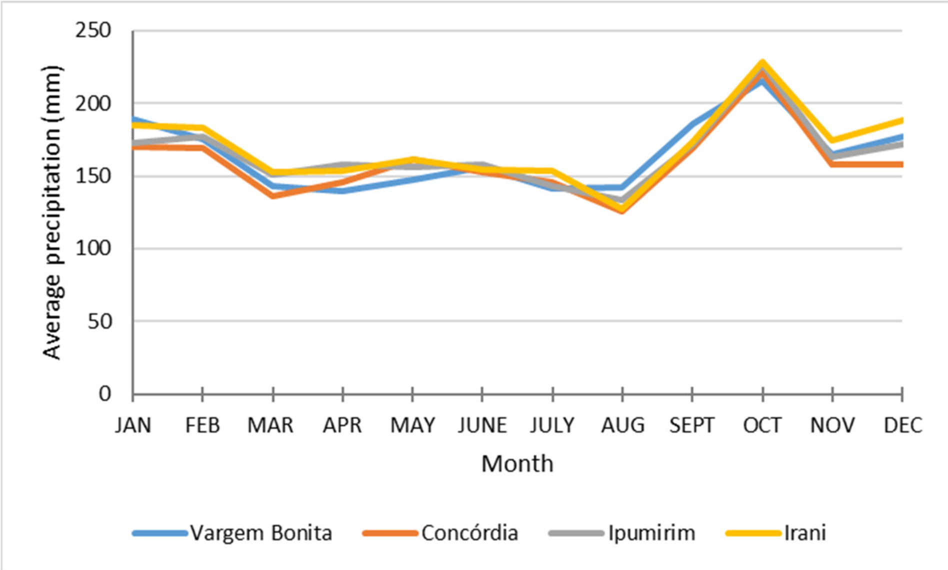

Figure 2. Distribution of average annual precipitation of the four pluviometric stations used.

Table 5. Potential CAFO supply by RWHSs.

Productive Category		V_a † (10^3 m^3/year)	V_d ‡ (10^3 m^3/year)	r * (%)	σ (%)
Swine	Breeding sows	598.3	1784.9	33.5	1.0
	Piglets	274.2	416.0	65.9	1.0
	Growing–finishing pigs	2252.1	3749.4	60.4	1.0
Poultry	Layers	192.3	99.2	100	0.0
	Broilers	3319.6	2002.2	100	0.0

† rainwater volume available for catchment; ‡ water volume demand; * potential of water demand that can be supplied by rainwater in CAFOs; σ—standard deviation.

In poultry CAFOs, the water volume available to be captured on the roofs of the farms (V_a) proved to be able to supply 100% of the water volume demand (V_d) for CAFOs in both layer and broiler productive categories, indicating that the demand can be fully met by an RWHS (r = 100%). In accordance with the values obtained, a surplus of water from the total roof harvesting area can be generated with a chance to only use part of the farm roof. The results found for poultry CAFOs are consistent with those presented in the literature, in Medianeira-Paraná state, Brazil, with monthly rainfall averages between 90 and 275 mm [26]. The study showed that the water volume available to be captured on the roof of the farms should be sufficient to supply all the needs for animal production (water consumption and cleaning activities) over at least 15 days with a maximum consumption of 1000 m^2 from the roof and 12,000 birds, also generating a surplus. The 15 days were related to the conventional period of drought in the region, mentioning the use of the cistern to increase water storage capacity and also to minimize problems related to a lack of water in these critical periods.

Figures 3 and 4 exhibit the water-saving potential, in terms of annual average volume, for the swine and poultry CAFOs, respectively, for each of the 19 municipalities located in the region of study. Figure 5 shows the associated result for the potential of swine and poultry CAFOs.

The results showed that although the potential for water supply demand (r) was less than 100% in the swine farms, the use of RWHSs in the different productive categories in the study region resulted in a higher water economy when compared with the poultry CAFOs. This is due to the numerous swine herds and the high water demand necessary for production. In these cases, the RWHS should be used in conjunction with other water sources. Other nearby harvesting areas can be used to maximize rainwater utilization potential.

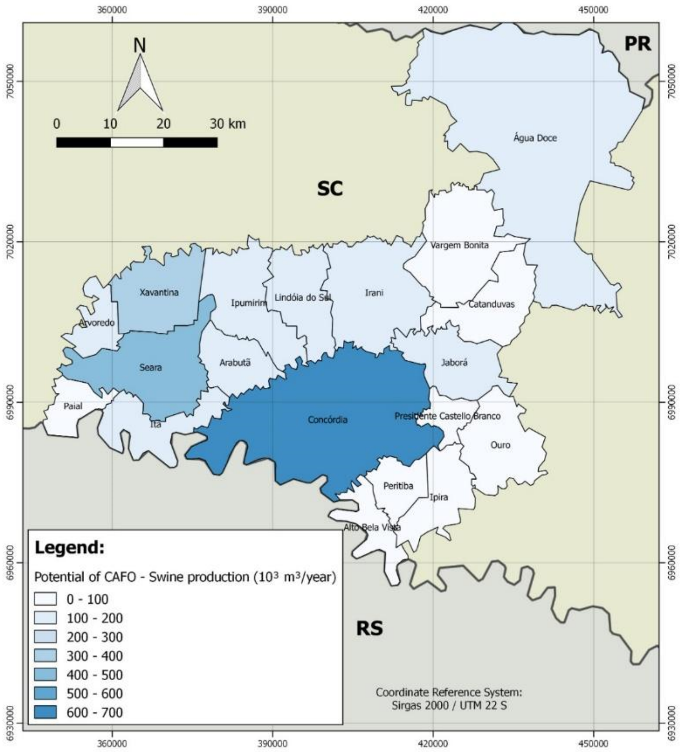

Figure 3. Water—saving potential (R) in swine CAFOs for RWHS use.

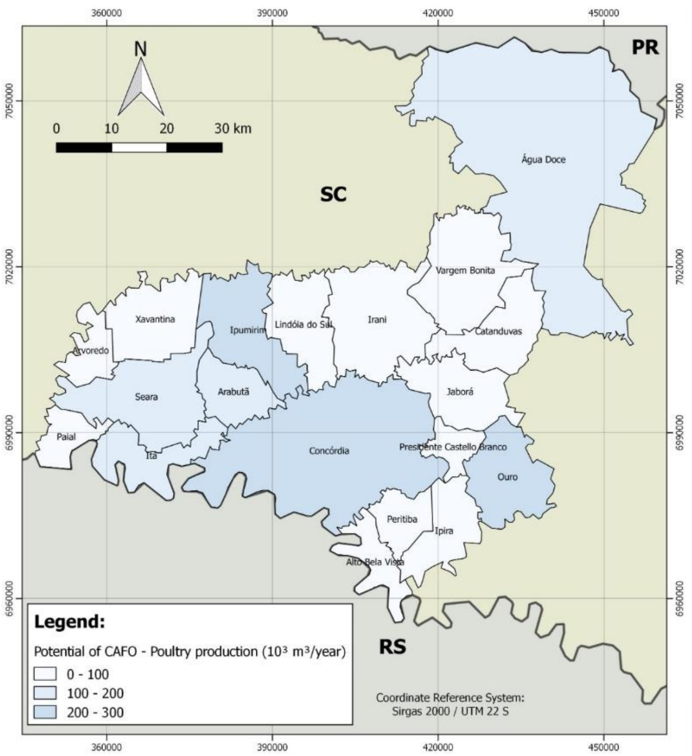

Figure 4. Water—saving potential (R) in poultry CAFOs for RWHS use.

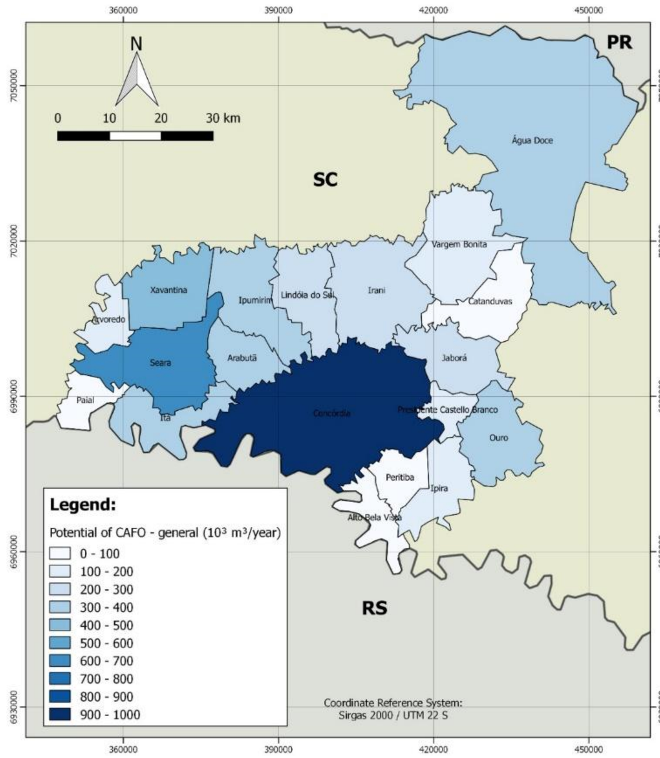

Figure 5. Water—saving potential (R) in poultry and swine CAFOs for RWHS use.

The contribution of each productive category to the potential of water from RWHSs used in each municipality varies according to the number of animals. The swine and poultry productive chains, in general, were responsible for 59.8% and 40.2% of the potential of total water volume use, respectively.

The sum of the water-saving potential of all CAFO categories in the entire study area was 5.2 million m^3 per year, which represents a withdrawal flow of 0.166 m^3/s. This value represents about 8% of the total withdrawn in Brazil: 2.048 m^3/s [4]. In comparative terms, this volume would be enough to supply a municipality with around 123,400 inhabitants, considering the average Brazilian consumption of 116 L per inhabitant per day [27].

The municipality of Concórdia presented the greatest water-saving potential, in terms of annual volume, with a total amount of 934,300 m^3. This result is a consequence of the number of animals produced in the municipality, having the largest number of pigs and poultry among the municipalities in the region of the study (Table 2). The contribution of swine farms represented 71.1% of Concórdia's annual volume of water-saving potential (Figure 5), being the most representative productive category of the growing–finishing phase, with 52.3% of the total potential volume (488,200 m^3). A similar result was observed in Seara and Xavantina municipalities, with the second and third largest potentials in total water volume, respectively. In Xavantina, the representativeness of swine farms corresponded to 85.8% of the annual potential water volume, due to the considerable increase associated with a large number of breeding sows, responsible for 26.6% of the potential determined. In the municipalities of Ipumirim, Arabutã, and Ouro, determined as the fourth, fifth, and sixth highest potentials in the annual potential water volume, respectively, the poultry CAFOs presented more representativeness for the potential of water use from the RWHSs. In Ouro, the broilers category was responsible for 75.0% of the annual potential water volume due to the number of animals housed in the region of study, the second highest after the Concórdia municipality.

The water fragility of the municipalities studied, due to the high concentration of CAFOs, was another item considered. For this, the water-saving potential per area was determined, resulting in an average of 1000 m^3 per km^2 per year. Figure 6 shows the evaluation performed in each municipality of the study area.

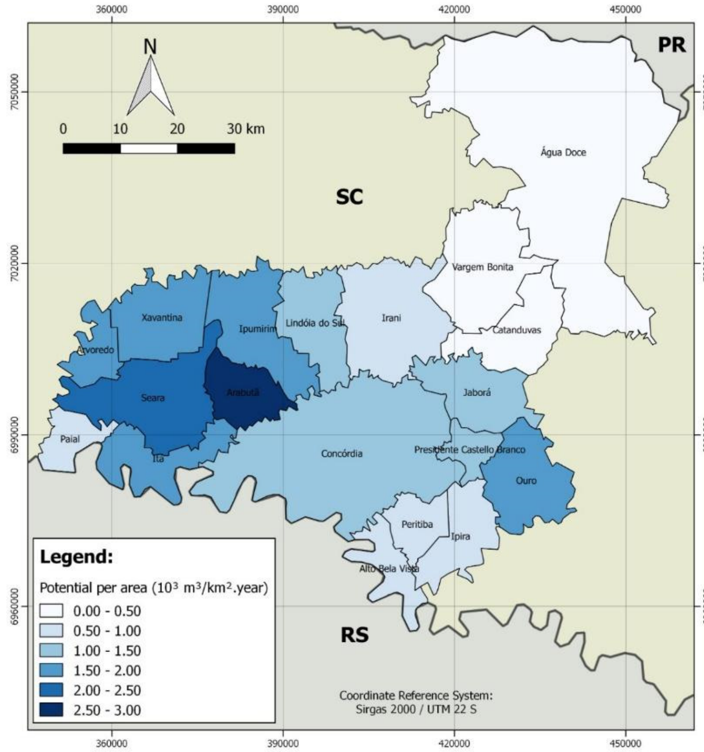

Figure 6. Water—saving potential per area from RWHS use in the municipalities of the Jacutinga River Basin and Contiguous Basins Management Committee region.

The municipality of Arabutã, in fifth position in the annual potential water volume ranking, showed the highest water-saving potential by area, with an average value of 2760 m^3 per km^2 per year. This result can be explained by the large concentration of CAFOs (swine and poultry) associated with a balanced production matrix in a small territory. This municipality presents, currently, the fourth largest number of animals between the 19 municipalities located in the region of the Management Committee of the Jacutinga River Basin and Contiguous Basins, and the representativeness of both productive categories was balanced in the potential of RWHSs to supply the water demand, with 48% and 52%, respectively, coming from swine and poultry CAFOs. In addition, Arabutã showed great potential for the use of RWHSs to supply the water demand in CAFOs among its territory, where the application of these systems can substantially reduce the pressure exerted by livestock over the local water resources.

The municipality of Concórdia obtained the largest annual volume of water-saving potential (m^3/year) in the region of the study, but it was only determined as the tenth highest in relation to potential by area, with 1220 m^3 per km^2 per year. In this sense, the concentration of CAFOs was lowest in this municipality, far below that observed in Arabutã.

A greater potential per area was perceived in the municipalities of the western region of the study area, in general, which indicates a greater pressure on the region's water resources by the CAFOs. The municipality of Água Doce, the highest in terms of area, although determined as the seventh in relation to the potential in the annual potential water volume, is in last position in the potential by area, indicating a lower concentration of CAFOs and a better-distributed water demand.

4. Conclusions and Recommendations

The average precipitation determined for each municipality, and the respective distribution over the year (1963 $\pm$ 41 mm per year), showed the RWHSs to be a promising alternative to achieve water security in both swine and poultry CAFO farms, considering the region of the Jacutinga River Basin and Contiguous Basins Management Committee.

The historical standardized series of precipitation, over 42 years (1977–2018), showed that good management of the area available for collection, and the respective water collected, associated with the use of cisterns for storage, may allow the use of this resource not only as an emergency source in cases of droughts but also as a primary and constant source of water for the productive categories evaluated.

The potential of water demand that can be supplied by rainwater (r) in CAFOs was 100% for poultry production and between 32.7% and 68.3% for swine production. Even though rooftop RWHSs did not show the potential to fully meet the water demand from swine CAFOs, the water-saving potential in volume terms was higher than poultry CAFOs due to high water demand and the numerous swine herds. The collection of water from neighboring roofs and/or an option of joint RWHSs in both swine and poultry farms may allow an increase in the potential to attend to the demand. The total water-saving potential ($\sum$R) for RWHS use in swine and poultry CAFOs in the study area was 5.2 million m^3 per year.

A greater potential per area was perceived in the municipalities in the western region of the study area, in general, which indicates a greater pressure on the region's water resources by the CAFOs. The inclusion of the RWHS uses for livestock production in public policies and as governmental management tools (state or federal) may be considered a decision/management tool for local resources, minimizing the pressure on underground and surface water sources and the economic impacts associated with droughts.

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References

1. Matthiensen, A.; Schmidt, N.S. Água na Avicultura de Postura. *Avic. Ind.* **2018**, *1281*, 14–21. Available online: https://www.aviculturaindustrial.com.br/edicao/1281 (accessed on 6 May 2021).
2. UNESCO, UN-WATER. *United Nations World Water Development Report 2020: Water and Climate Change*; UNESCO: Paris, France, 2020; 219p. Available online: https://www.unwater.org/publications/world-water-development-report-2020/#:~{}:text=The%202020%20United%20Nations%20World,addressed%20through%20improving%20water%20management. (accessed on 5 May 2021).
3. Regelmeier, F.A.; Kozerski, C.E. Aproveitamento de Água da Chuva em Zonas Rurais: Captação e Reservação. In Exposição De Experiências Municipais Em Saneamento, 19; Assembleia Nacional Da Assemae, 35, Poços de Caldas. 2015; Available online: http://www.trabalhosassemae.com.br/sistema/repositorio/2015/1/trabaflhos/218/363/t363t5e1a2015.pdf (accessed on 5 May 2021).
4. Brasil. Agência Nacional das Águas (ANA). Conjuntura dos Recursos Hídricos no Brasil 2019: Relatório Anual. Brasília. 2019. Available online: http://www.snirh.gov.br/portal/snirh/centrais-de-conteudos/conjuntura-dos-recursos-hidricos/conjuntura_informe_anual_2019-versao_web-0212-1.pdf (accessed on 15 March 2021).
5. ABPA (Associação Brasileira de Proteína Animal). Relatório Anual 2020. São Paulo: ABPA. 2020. 158p. Available online: http://abpa-br.org/relatorios/ (accessed on 23 August 2022).

6. Brasil. Instituto Brasileiro de Geografia e Estatística (IBGE). Pesquisa Pecuária Municipal (PPM), 2018 Efetivo dos Rebanhos, por Tipo de Rebanho. Rio de Janeiro. Available online: https://www.ibge.gov.br/estatisticas/economicas/agricultura-e-pecuaria/9107-producao-da-pecuaria-municipal.html?edicao=25474&t=resultados (accessed on 5 September 2022).
7. Comassetto, V.; Matthiensen, A.; Alves, J.; Favassa, C.T.A.; Yabiku, V.M.; Waskiewic, M.E.; Bólico, B. Diagnóstico das Águas Subterrâneas na Bacia do Rio Jacutinga e Contíguos. In Congresso Brasileiro De Águas Subterrâneas, 19; Encontro Nacional De Perfuradores De Poços, 18; Feira Nacional Da Água-Fenágua, 8. Belo Horizonte. 2014. Available online: https://repositorio.ufsc.br/handle/123456789/200485 (accessed on 5 May 2021).
8. Waskiewic, M.E.; Comasseto, V.; Titon, M.A.; Giron, J.; Favassa, C.T.A.; Matthiensen, A. Dinâmica de Uso de Cisternas no Contexto da Gestão Integrada da Água na Bacia Hidrográfica do Rio Jacutinga e Contíguos (SC). In Simpósio Brasileiro De Recursos Hídricos, 22. Florianópolis. 2017. Available online: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/179602/1/final8583.pdf (accessed on 13 March 2021).
9. Catarina, S. Lei nº 14.675, de 13 de Abril de 2009. Institui O Código Estadual do Meio Ambiente e Estabelece Outras Providências. 2009. Available online: http://leis.alesc.sc.gov.br/html/2009/14675_2009_Lei.html#:~{}:text=Institui%20o%20C%C3%B3digo%20Estadual%20do%20Meio%20Ambiente%20e%20estabelece%20outras%20provid%C3%AAncias.&text=das%20DISPOSI%C3%87%C3%95ES%20GERAIS-,Art.,qualidade%20ambiental%20no%20seu%20territ%C3%B3rio (accessed on 5 May 2021).
10. Hoss, C.H. Sistemas de Aproveitamento de Água da Chuva Utilizados na Produção de Suínos e Aves. Master's Thesis, Universidade Federal de Santa Catarina, Florianópolis, Brasil, 2017.
11. Tucci, C.E.M. *Hidrologia: Ciência e Aplicação*; UFRGS: Porto Alegre, Brasil, 2007; 943p.
12. Brasil. Agência Nacional das Águas (ANA). Hidroweb. 2019. Available online: https://www.snirh.gov.br/hidroweb/ (accessed on 15 March 2021).
13. Tomaz, P. *Aproveitamento de Água da Chuva em Áreas Urbanas Para Fins Não Potáveis*; Plínio Tomaz: São Paulo, Brasil, 2009; 34p.
14. ABCS/SEBRAE (Associação Brasileira dos Criadores de Suínos/Serviço Brasileiro de Apoio às Micro e Pequenas Empresas). Bem-Estar Animal na Produção de Suínos: Toda Granja. Brasília. 2016. Available online: https://www.sebrae.com.br/Sebrae/Portal%20Sebrae/UFs/RN/Anexos/suinocultura-Bem-estar-Animal-na-Producao-de-Suinos-Toda-granja.pdf (accessed on 5 September 2022).
15. Russo, J.C. Tudo Que Você Precisa Saber Sobre os Sistemas de Produção de Ovos. Avicultura Industrial. 2019. Available online: https://www.aviculturaindustrial.com.br/imprensa/tudo-que-voce-precisa-saber-sobre-os-sistemas-de-producao-de-ovos/20190326-113131-t740 (accessed on 5 May 2021).
16. Miele, M.; De Abreu, P.G.; Abreu, V.M.N.; Jaenisch, F.R.F.; Martins, F.M.; Mazzuco, H.; Trevisol, I. Coeficientes Técnicos Para o Cálculo do Custo de Produção de Frango de Corte. Comunicado Técnico 483, Embrapa Suínos e Aves, Concórdia. 2010. Available online: http://www.cnpsa.embrapa.br/sgc/sgc_publicacoes/publicacao_e3k24c1s.pdf (accessed on 5 May 2021).
17. Catarina, S.; Intituto do Meio Ambiente de Santa Catarina (IMA). Instrução Normativa n.º 11, Florianópolis, Brasil. 2014; 37p. Available online: https://in.ima.sc.gov.br/ (accessed on 5 September 2021).
18. Tavares, J.M.R.; Belli Filho, P.; Coldebella, A.; Oliveira, P.A.V. The water disappearance and manure production at commercial growing-finishing pig farms. *Livest. Sci.* **2014**, *169*, 146–154. [CrossRef]
19. Viola, E.S.; Viola, T.H.; de Lima, G.J.M.M.; de Avila, V.S. Água na Avicultura: Importância, Qualidade e Exigências. In *Manejo Ambiental na Avicultura*; Palhares, J.C., Kunz, A., Eds.; Documentos 149; Embrapa Suínos e Aves: Concórdia, Brasil, 2011; pp. 37–123. Available online: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/57058/1/agua-na-avicultura.pdf (accessed on 4 January 2022).
20. Hy-Line. Manual de Manejo: Poedeiras Comerciais Hy-Line Brown. November 2018. 29p. Available online: https://www.hyline.com/filesimages/Hy-Line-Products/Hy-Line-Product-PDFs/Brown/BRN%20COM%20POR.pdf (accessed on 5 September 2022).
21. De Oliveira, P.A.V. Uso Racional da Água na Suinocultura. Embrapa Suínos e Aves. In Curso de Capacitação Em Práticas Ambientais Sustentáveis: Treinamentos 2002, Concórdia. 2002, pp. 63–71. Available online: https://www.bdpa.cnptia.embrapa.br/consulta/busca?b=pc&id=435029&biblioteca=vazio&busca=autoria:%22EMBRAPA%20SUINOS%20E%20AVES.%22&qFacets=autoria:%22EMBRAPA%20SUINOS%20E%20AVES.%22&sort=&paginacao=t&paginaAtual=1 (accessed on 5 May 2021).
22. Tavares, J.M.R.; Department of Technologies and Applied Sciences, School of Agriculture, Polytechnic Institute of Beja and Fiber Materials and Environmental Technologies (FibEnTech-UBI), Beja, Portugal. Personal communication, 2019.
23. Tavares, J.M.R. Consumo de Água e Produção de Dejetos na Suinocultura. Master's Thesis, Universidade Federal de Santa Catarina, Florianópolis, Brasil, 2012. Available online: https://repositorio.ufsc.br/xmlui/handle/123456789/100704 (accessed on 5 May 2021).
24. De Lima, J.A.; Dambros, M.V.R.A.; De Antonio, M.A.P.M.; Jansen, J.G.; Maechetto, M. Potencial da Economia de Água Potável Pelo Uso de Água Pluvial: Análise de 40 Cidades da Amazônia. *Eng. Sanitária Ambient.* **2011**, *16*, 291–298. Available online: https://www.scielo.br/j/esa/a/F7sqjkgMFvKrVWH48JHw7tr/?lang=pt (accessed on 5 September 2022). [CrossRef]
25. Maykot, J.K.; Ghisi, E. Assessment of a rainwater harvesting system in a multi-storey residential Building in Brazil. *Water* **2020**, *12*, 546. [CrossRef]

26. Proença, G.G.; Schmidt, C.A.P. Aproveitamento de Água da Chuva: Um Dimensionamento para o Caso de Aviários. *Revista DAE* **2014**, *197*, 26–30. [CrossRef]
27. Brasil. Instituto Brasileiro de Geografia e Estatística (IBGE); Agência Nacional da Águas (ANA). Contas Econômicas Ambientais da Água: Brasil 2013–2017. Ed. 72. Rio de Janeiro. 2020. Available online: https://biblioteca.ibge.gov.br/visualizacao/livros/liv101710_notas_tecnicas.pdf (accessed on 5 May 2021).