Conjecturas

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Sustainability of domestic greywater reuse in family farming

Sustentabilidade da reutilização doméstica de águas cinzentas na agricultura familiar

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ABSTRACT

The reuse of wastewater can combine environmental preservation and high agricultural productivity, mainly by minimizing the pressure on water withdrawal. The Family Bio-water System uses domestic greywater for family farming, being an alternative for food production in the backyards of farming families in places that suffer from water scarcity. Aiming to evaluate the environmental and socio-economic sustainability of these systems, 13 units were analyzed in the rural area of the municipalities in the state of Ceará. The MESMIS method was used, based on indicators composed of Water Resources; Soil Quality; Health Situation; Work and Relationships; Economic Situation; Adaptation; Productivity; and Self-Management, as well as microbiological and physical-chemical data of the reused water. The results confirm that the systems presented good pollutant removal efficiency, with the exception of *Escherichia coli*, which requires attention because it presents health risks. It was evidenced that the agroecosystems are sustainable and that the integration of socio-environmental, technical, and economic criteria is relevant to support the decision-making of the families benefited by the system.
Keywords: Water reuse; Irrigation; Semiarid; Agroecosystems; Indicators

RESUMO

A reutilização das águas residuais pode combinar a preservação ambiental e a elevada produtividade agrícola. O Family Bio-water System utiliza água cinzenta doméstica para a agricultura familiar, sendo uma alternativa para a produção de alimentos nos quintais das famílias de agricultores em locais que sofrem de escassez de água. Com o objectivo de avaliar a sustentabilidade ambiental e socioeconómica destes sistemas, foram analisadas 13 unidades na zona rural dos municípios no estado do Ceará. Foi utilizado o método MESMIS, baseado em indicadores compostos por Recursos Hídricos; Qualidade do Solo; Situação de Saúde; Trabalho e Relações; Situação Económica; Adaptação; Produtividade; e Auto-Gestão, bem como dados microbiológicos e físico-químicos da água reutilizada. Os resultados confirmam que os sistemas apresentaram uma boa eficiência na remoção de poluentes, com excepção da *Escherichia coli*, que requer atenção porque apresenta riscos para a saúde. Foi demonstrado que os agroecossistemas são sustentáveis e que a integração de critérios sócio-ambientais, técnicos e económicos é relevante para apoiar a tomada de decisão das famílias beneficiadas pelo sistema.
Palavras-chave: Reutilização da água; Irrigação; Semi-árido; Agroecossistemas; Indicadores.

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INTRODUCTION

Graywater is a resource continuously produced in family households and can be used in food production, thus reducing the demand for more noble waters, and such effluent can also play a role as a source of nutrients for plants (Bizari & Cardoso, 2016). There is a growing and genuine interest in the use of recycled treated sewage water as an alternative source of water for irrigation.

The Brazilian semi-arid region, known for suffering constant water shortage, needs strategies to mitigate the impacts generated by drought, caused mainly by climatic conditions. A potential alternative for the rationalization of this natural resource is its reuse for activities that do not require a very high level of quality, such as agricultural irrigation, especially because water deficit is also directly related to food shortages (Travis et al., 2010).

Reuse is a practice adopted in many countries and is becoming increasingly common in Brazil, which can occur directly or indirectly, through planned or unplanned actions (Handam et al. 2021). Reused water can come from treated domestic or industrial effluents, and its applicability will depend, besides local needs, on the level of water quality required and the flow rate produced. According to Hespanhol (2008), the different potential modalities of reuse depend on local characteristics, conditions and factors, such as political decision, institutional schemes, technical availability and economic, social and cultural factors.

Greywater is the domestic effluent that has no contribution from the sanitary basin, therefore the effluents generated by the use of showers, bathtubs, sinks, washbasins and washing machines or tanks (Hespanhol 2008). The Family Bio-water System (SBF), graywater reuse systems for family farming, is an alternative for food production and reduction of environmental contamination in the backyards of farming families in the Brazilian semiarid region (Santiago et al. 2015). The technology consists of a physical and biological treatment and follows the principles of agroecology, a holistic and systemic approach that supports the search for more sustainable alternatives to the hegemonic conventional style of agriculture by integrating agronomic, ecological, and socioeconomic principles (Caporal et al. 2006). Moreover, this social technology has low cost and is being increasingly disseminated in Brazil, especially in Northeastern states.

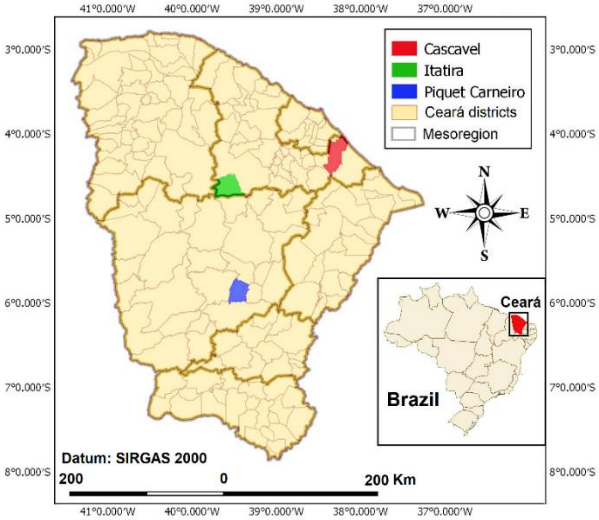
The present work aimed to evaluate the environmental and socioeconomic sustainability of FBS in 13 agroecosystem units in the rural zone of Ceará state, using composite indicators through the MESMIS method (Marco para Evaluación de Sistemas de Manejo de Recursos Naturales Incorporando Indicadores de Sustentabilidad) (Masera et al. 2000). These indicators are able to indicate the situation of the units, and propose an evaluation form capable of verifying the valuation of water and decision making for the application of an effective water management model in regions that suffer from water scarcity.

METHODS

This is a case study, in which secondary and primary data collection and analysis were performed using questionnaires, interviews, measurement and observation (Minayo & Sanches 1993). This study was reviewed and approved by the Ethics Committee on Human Research of the Escola Nacional de Saúde Pública/Fiocruz (CAAE no. 87564718.0.0000.5240). Among the data collection activities, field observation and analysis of laboratory data on the quality of reuse water and irrigated soil were performed, as well as the application of two structured questionnaires to the farming families. Questionnaire 01 had the objective of tracing the socioeconomic and public health profile, and comparing the conditions of the families with and without greywater reuse systems for irrigation (applied to 15 families without the system and 13 with the system). Questionnaire 02 subsidized the characterization of the use and sustainability of the agroecosystems that use the reuse technique, as well as its impacts on the families. In total, 13 FBS's implemented in productive backyards were evaluated, in the state of Ceará, in the Cristais district, municipality of Cascavel (9 houses); in the Aba da Serra community (9 houses), municipality of Piquet Carneiro; and in the Umarizeiras settlement, municipality of Itatira (10 houses) (Figure 1).

The evaluation of the environmental and socioeconomic sustainability of the systems was carried out using the Framework Method for Evaluating Natural Resource Management Systems Incorporating Sustainability Indicators (MESMIS), proposed as a methodology to evaluate agroecosystems using indicators (Masera et al. 2000) constituted based on farmers' accounts and field observations. Sustainable agricultural systems need to have attributes such as: productivity, stability, resilience, reliability, adaptability, equity, and self-dependence. The following stages were carried out: detailing of the agroecosystems evaluated, identifying the management systems, their characteristics and socio-economic and environmental context; analysis of the critical points existing in the agroecosystems; identification of the limiting and positive factors related to sustainability; analysis of the diagnostic indicators; measurement of the indicators (qualitative and quantitative) with the use of tables and notes (Table 1).

Figure 1 – Location of the three rural communities, in the state of Ceará, Brazil



The result of each composite indicator was equivalent to the average of the simple indicators that compose it. The grades established represented the levels of sustainability, being the maximum grade of 3.00, ideal or desirable situation (marked in green, values from 2.1 to 3.0), and the minimum grade of 1.00, undesired condition (marked in red, values from 0 to 1.0), and between them the regular situation, with a grade of 2.00 (marked in blue, values from 1.1 to 2.0). Intermediate scores were also used, in situations that did not fit in any of the cases or even fit in two different ones.

The results were schematized in radial graphs in order to make a transversal comparison among all the systems and in relation to a hypothetically desirable reference situation. The positive and negative aspects were related in relation to the changes resulting from the reuse for both the benefited families and the communities studied, comparing the period before the implementation of the systems to the later and current period, with the practice of reuse.

Table 1. Composite Sustainability Indicators (ISC) and their respective Simple Sustainability Indicators (ISS).

ISC	ISS	ISC	ISS
Water resources	Domestic Water Availability	Adaptation	Satisfaction
(ISCRH)	Agricultural water availability	(ISCAD)	Ecological awareness
	Agricultural water quality		Search for alternatives
Soil Quality	pH		Agricultural water use
(ISCQS)	Phosphorus		Participation
	Organic Matter		Contact with other families
	Base saturation		Agro-ecological practices
Health situation	Health status	Productivity	Plant Diversity
(ISCSS)	Improved eating habits	(ICSCP)	Plantation condition
	Change in eating habits		Stability
	Sanitation-related diseases		Resiliency
Labor and relations	Labor		External Inputs
(ISCTR)	Permanence in the field	Self-management	Maintenance of inputs
	Occupation level	(ISCAU)	Generation of waste or residue
Economic Situation (ISCSE)	Financial income		Maintenance of system components
	Commercialization		Organization
			Technical dependence

The water quality was analyzed based on data from the laboratory analyses performed by the Secretary of Agrarian Development of Ceará (SDA), which followed the Standard Methods for the Examination of Water and Wastewater (SMEWW 2005). The mean values of the results of the four monitoring campaigns, per parameter and for each system, were compared to the standards with Maximum Allowable Values (MAV) specifically described for agricultural reuse, available in national and international sources of standards, resolutions and legislation that had described physicochemical and biological parameters (Table 2).

After the selection of the specific parameters by the legislation and standards in force for agricultural reuse water, besides the analysis of whether the treated greywater was within the standards, the analysis of the performance of the treatment and the efficiency of pollutant removal was performed. For the performance, the parameters with results outside the standard at the entrance of the system were identified, and the data of the same parameters at the exit of the systems were identified, and the treated effluent, therefore the reuse water ready to be used in agricultural irrigation, if it was still outside the standard or if it was corrected in accordance with the allowed values. The contaminant removal efficiency was calculated according to the reduction in the concentration of components present in the water by comparing the upstream raw graywater with the downstream treated reuse water (Boano et al., 2020). The parameters analyzed in this step were Turbidity, Total Suspended Solids, BOD, QOD and *E. coli*.

Table 2. Parameters for agricultural reuse, described in national and international standards.

Parameter	MAV	Unit	Reference
pH	6 - 9	-	USEPA, 2012 (Guidelines for water reuse)
Electrical Conductivity	3000	µS/cm	SEMACE - CE, 2002 (Portaria Nº 154)
Sodium	70	mg/l	CONERH - BA, 2010 (Resolução Nº 75)
Sodium Adsorption Ratio (SAD)	9	((mmolcl-1)0,5)	CONERH - BA, 2010 (Resolução Nº 75)
Total Suspended Solids (TSS)	100	mg/l	Manual PROSAB, 2006
Total Dissolved Solids (TDS)	2000	mg/l	USEPA, 2012 (Guidelines for water reuse)
Bicarbonates	500	mg/l	USEPA, 2012 (Guidelines for water reuse)
Chlorides	350	mg/l	CONERH - BA, 2010 (Resolução Nº 75)
Nitrate	30	mg/l	USEPA, 2012 (Guidelines for water reuse)
Biochemical Oxygen Demand (BOD)	10	mg/l	USEPA, 2012 (Guidelines for water reuse)
Geohelminth eggs	1	eggs/l	SEMACE - CE, 2002 (Portaria Nº 154)
E. coli	1000	MPN/100 ml	SEMACE - CE, 2002 (Portaria Nº 154)

RESULTS

In the characterization of sanitation conditions, the families without reuse systems were included in order to evaluate the panorama regarding water and sewage conditions, with a total of 28 families. The predominant supply source in all three communities was the Integrated Rural Sanitation System (SISAR), a Non-Governmental Organization institutionally supported by the State and that seeks the universalization of access to water in rural areas of Ceará. However, the families almost always relied on another source of supply, such as rainwater, with storage in cisterns, or well water piped directly to the taps (Table 3).

For drinking water, all use rainwater, with the exception of the community of Aba da Serra, because it was not contemplated with the One Million Cisterns Program (P1MC), so most of these families buy water from a well water desalinizer, from the Fresh Water Program, both from the former federal government. The reports of storage in water tanks and cisterns prevailed, but there were families who also stored in jars or containers and in tanks (Table 4). There were families that, in addition to the traditional primary consumption cisterns, also had calçadão type cisterns, intended for irrigation water, which can hold a larger volume of water. Some even said that they "keep" not only the rainwater in this cistern, but also the water from the network itself, to prevent shortages in dry periods, so that the cisterns always have water.

Table 3. Characteristics of sanitation conditions in three rural communities in Ceará state, CA: Cascavel; PQ: Piquet Carneiro; IT: Itatira, Brazil (n= 28).

Aspects evaluated	CA		PC		IT		Total	
	n(%)		n(%)		n(%)		(n(%)	
With agrosystem	4		4		5		13	
Without agrosystem	5		5		5		15	
Water Supply Source								
-Network	9	(100.0)	9	(100)	10	(100)	28	(100.0)
-Rainwater	3	(33.3)	-		-		3	(10.7)
-Well	2	(22.2)	-		-		2	(7.1)
-Fountain	1	(11.1)	-		-		1	(3.6)
Source of drinking water								
-Rainwater	9	(100.0)	-		10	(100.0)	19	(67.9)
- Purchased	1	(11.1)	7	(77.8)	-		8	(28.6)
- General Grid	-		1	(11.1)	-		1	(3.6)
- Dam	-		1	(11.1)	-		1	(3.6)
Lack of water								
-Sporadic	6	(66.7)	7	77.8	4	(40.0)	17	(60.7)
-Sporadic	2	(22.2)	-		-		2	(7.1)
-Frequent	1	(11.1)	-		5	(50.0)	6	(21.4)
-Never	-		1	11.1	-		1	(3.6)
-Sporadic (during drought)	-		1	11.1	-		1	(3.6)
Don't know	-		-		1	(10.0)	1	(3.6)
Water Storage								
-Tank	1	(11.1)	-		1	(10.0)	2	(7.1)
- Containers	2	(22.2)	4	(44.4)	2	(20.0)	8	(28.6)
- Cistern	3	(33.3)	-		9	(90.0)	12	(42.9)
- Water tanks	8	(88.9)	8	(88.9)	9	(90.0)	25	(89.3)
Gray Water Dentin								
-Tossa	1	(11.1)	-		-		1	(3.6)
- Plantation	3	(33.3)	4	(44.4)	5	(50.0)	12	(42.9)
- Land	4	(44.4)	5	(55.6)	5	(50.0)	14	(50.0)
- Recycling in the agrosystem	4	(44.4)	4	(44.4)	5	(50.0)	13	(46.4)
Fate of the black water								
Trench	9	(100.0)	9	(100.0)	10	(100.0)	28	(100.0)

About the destination of the residuary waters, all the benefited families had, before the implanted systems, the destination of the gray water directly into the soil of the land, without any kind of treatment, and the destination of the black water into a fossa installed in the backyard of the house (Table 3).

The composite indicators that indicated in all communities, that the agroecosystems studied are linked to the practice of sustainable reuse, with scores in the desirable situation range (green) were: "Water Resources" (ICSRH); "Health Situation" (ICSSS); "Economic Situation" (ICSSE); "Adaptation to Agroecosystems" (ICSAD); and "Self-Management" (ICSAU) (Table 4). The composite indicator "Productivity" (ICSCP) had an average score of 2.13, almost at the limit of the desirable range with regular, as the communities of Cascavel and Piquet Carneiro were in a regular situation. The same occurred for the composite indicator "Labor and its Relationships" (ICSTR), which had an average score of 2.08, as the communities of Cascavel and Itatira were in a regular situation. The composite indicator that had the lowest average score in the study and had the lowest scores in all communities (Table 4) was "Soil Quality" (ICSQS), 1.90, with the exception of one of the communities, which obtained an individual score for this indicator of 2.50, while the rest were between 1.75 and 2.0, regular level. No indicator was found in the undesirable range (between 0.00 and 1.00).

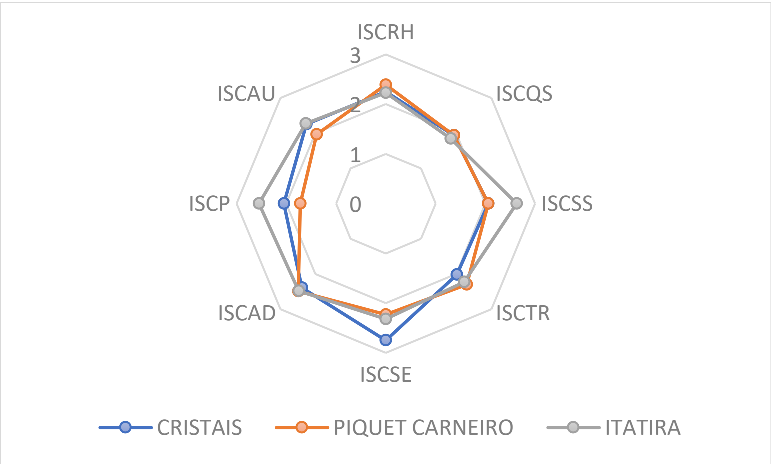
Table 4. Average scores calculated for the set of composite indicators (CSI), with respective band marks (M): 0 to 1 (red) = undesired condition); 1.1 to 2.0 (blue) = regular situation; 2.1 to 3.0 (green) = desirable condition.

Composite Indicators	CA	PC	IT	Total
	ISC(M)	**ISC(M)**	**ISC(M)**	**ISC(M)**
Water Resources (ICSRH)	2.25	2.39	2.23	2.29
Soil Quality (ICSQS)	1.94	1.94	1.85	1.90
Health Situation (ICSSS)	2.06	2.06	2.63	2.28
Labor and Relationships (ICSTR)	1.94	2.23	2.08	2.08
Economic Situation (ICSSE)	2.75	2.38	2.23	2.44
Adaptation (ICSAD)	2.39	2.47	2.47	2.44
Productivity (ICSCP)	2.06	1.69	2.54	2.13
Self-management (ICSAU)	2.22	2.17	2.17	2.12

In the integrated analysis of the composite indicators, considering each agrosystem, the most sustainable productive systems were those of Cristais and Itatira, with General Sustainability Indexes (GSI) of 2.56 and 2.57, respectively, indicating that they are in a good state of sustainability, on the way to reaching the ideal. The great majority of the systems presented indices above 2.00, with only Cristais scoring below this level.

These results are consistent with field observations in verifying the dynamics of the systems. The situation of the indicators, almost all, also with the exception of only one (ISCQS), obtained general values above 2.00, however, none managed to reach the score of 2.50. The ones that presented the best condition are the Economic Situation and Adaptation, both with general Composite Sustainability Indicators (ISC) worth 2.44, indicating good sustainability conditions. In general, in the Umarizeiras settlement, in Itatira, it was the agroecosystems that presented better levels of sustainability, with more positive results (Figure 2).

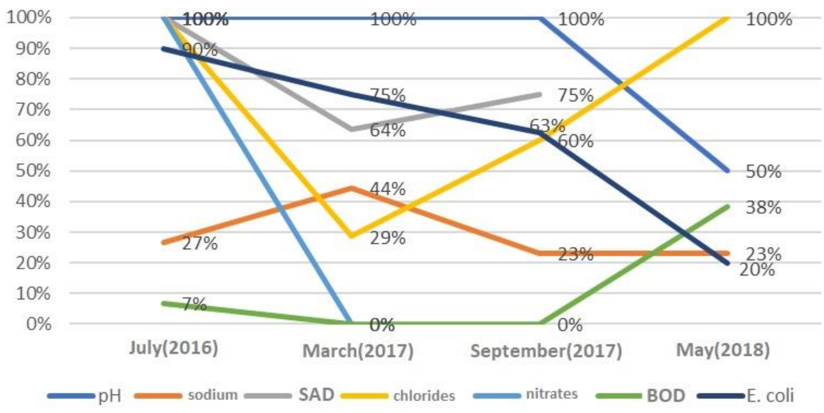
Figure 2 - Comparison of sustainability indicator levels for each composite indicator by location.



Source: Authors

In the analysis of the monitoring of the treatment performance, it was observed that in the first campaign, July 2016, the best result was obtained, with most parameters with 100% or 90% corrected, having only Sodium and BOD with more worrying values. These two parameters maintained a proportion below 50% throughout the monitored period, indicating that they really need more attention. In contrast, in the last monitored period, in May 2018, presented worse situation with most of the parameters with proportions below 50% correction, having only Chloride with a desirable result with 100% positive treatment (Figure 3). And as for the percentage of correction of the twelve parameters analyzed, the following results were: EC, TSS, TDS, Bicarbonates and Geohelminths had 100% correction; pH, SAD, E. coli and Chlorides, had respectively 92%, 72%, 68% and 53%. The worst correction levels were for the parameters Sodium (37%), Nitrate (33%) and BOD (11%).

Figure 3 - Agrosystem performance monitoring, by parameters and periods.



As for the efficiency of pollutants removal by the systems, the parameter, among the analyzed ones, which indicated the best average result was the Total Suspended Solids (TSS) with 91.44% of removal, followed by BOD, TB and QOD, being the average efficiency of removal of 86.99%, 82.53% and 80.83%, respectively. Finally, the parameter that presented the worst removal condition, among those analyzed, was E. coli, got the lowest average, with 28.65% removal (Figure 3).

DISCUSSION

The National Rural Sanitation Program (PNSR 2019) aims to promote and direct the development of basic sanitation actions in rural areas with a view to universal access, through strategies that ensure equity, integrality, intersectoriality, sustainability of the services implemented, and participation and social control. In the state of Ceará, what has promoted the search for the universalization of rural sanitation with such principles are the SISAR's present in the whole state, totaling 8 (eight), one per hydrographic basin, being a Management Model recognized nationally and internationally as promising for the promotion of safe access to drinking water. In this study, it was found that all three communities are served by the model, with all households connected to Water Supply Systems (WSS).

According to the Intermunicipal Environmental Sanitation Council (CISAM, 2006), the systems to be implemented, per isolated unit or per rural property, should always contemplate ease of operation and quality control, where a diversification of use may occur. As well as the National Policy of Basic Sanitation, established by Law 11.445/2007, which has as one of its guidelines the guarantee of appropriate means to meet the needs of the dispersed rural population, through the use of solutions compatible with their particular economic and social characteristics. According to what was observed in this research, the SBF meets these premises, being a solution of easy implementation and use, respecting the peculiarities of rural communities.

Graywater is domestic effluent that has a low content of organic matter and pathogenic microorganisms, compared to that coming from the toilet (blackwater), and can be reused for non-potable purposes, such as irrigation, as was the case in this study. In some regions, water is used for agricultural purposes in an informal way, without guaranteeing environmental and public health safety. It is becoming increasingly necessary to institutionalize, regulate, and promote this sector, with the creation of management structures, preparation of legislation, dissemination of information, and development of technologies for this purpose (Moura et al. 2020).

As for the composite indicator "Water Resources" (ICSRH), all communities had relatively sufficient amount of water from the general network to meet the basic needs of families, although some families reported weekly water shortages, especially in Itatira. The indicator for domestic water availability directly affects the operation of the systems, which depends on the amount of graywater produced in each household and has intrinsic influence on the indicator for agricultural water availability. One of the reasons for this indicator to have been at the lowest level of the desirable range (green), was the small number of people in the house, producing low volume of water available for irrigation, and the local conditions of high rates of evapotranspiration that occur in these regions with semi-arid climate making the plants require a greater water supply for better systemic interaction with the soil (Silva et al., 2019; Silva et al., 2021).

For the indicator "Soil Quality" (ICSQS), the level of Phosphorus was the one with the worst results, low scores of 1.15, indicating high concentrations of Phosphorus. These contents depend on the amount of clay in the soil, and there is no such data to consider the classes (Santiago 2015). On the other hand, organic matter, a very important indicator for soil fertility that depends very much on the management, obtained better results.

As for the indicator "Health Status" (ICSSS, it was found that most families had a change in eating habits, introducing healthy and more diversified foods in their daily lives after the use of FBS. This aspect is in line with SDG 2, which reports ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture by the year 2030.

For an agricultural system to be sustainable over time, it is essential that there is local labor working permanently, and that the number of people performing the necessary activities is sufficient to maintain its proper functioning, and it was in this context that the indicator "Labor and its Relations" (ICSTR) was analyzed. The low score of this indicator reflects the difficulty that most families are having with the activities performed, often resulting from health complications, and number of people working taken as insufficient; in only two systems they receive help from third parties (Astier et al., 2012). Another fundamental factor in the analysis of this indicator is the permanence of people in the countryside, especially young people, because besides being the ones to give continuity to future activities and generally having better health conditions to perform certain functions, they are the ones who have a greater tendency to migrate to urban areas. Rural communities still present inadequate conditions of technologies and education focused on the countryside, relying on teaching, culture and leisure to ensure the permanence of young people, leading to the problem of rural succession in family farming, resulting from the hyper valorization of the city (Brasil et al. 2020).

As for the indicator "Economic Situation" (ICSSE), it could be observed that although the systems focus on family subsistence, the assessment of Marketing was an indicator based on events prior to the implementation of the system, therefore allowed to assess improvements in this practice, further improving the financial situation of families. However, it was observed difficulty for families to have well-defined means or channels of commercialization, such as local producers' markets. The preference for local products with a short marketing circuit, in addition to systems of exchanges between families is a practice conducive to improving income, and not depending on the purchase of seeds (Astier et al., 2012).

Considering that the new agroecosystems were based on a different conception from conventional ones, which involved a whole dynamic around the reuse of water for irrigation, it was important to evaluate the adaptation of families based on the indicator "Adaptation to Agroecosystems" (ISCAD). All families reported being satisfied with the new agroecosystems, thus giving the indicator the best possible score. The families make modifications in order to adapt them to their way, with continuous improvement in the structure and functioning, but there were families that used other sources of water for irrigation, that is, a considerable part does not follow the recommendation given by the project, for they consider that the treatment systems produce little water and that it is insufficient to supply all the water needs of the cultivated area. Therefore, the need for contact with other contemplated families in the community to generate a support network can help in the adaptive process, and the better insertion of agro-ecological practices in their daily work, practices that are so important for the promotion of the sustainability of agroecosystems and that directly affect environmental health.

The composite indicator "Productivity" (ISCP), scored below 2.00 (regular status) in five implemented systems, and had the group average in the lowest range of desirable. This directly reflects the difficulty due, probably, to the prolonged drought that occurred in the northeastern region between the years 2012 and 2017 (Alvalá et al., 2019), and the difficulty in introducing new crops, thus depending on annual crops, traditional practices of families in the semiarid region (Brasil et al. 2020). Besides the difficulty of crop stability due to pests, plant diseases, and physical factors such as climate and soil quality (Masera et al. 2000).

The success of the composite indicator "Self-Management" (ISCAU) portrays the families' good management of the agroecosystems, such as the adequate use of organic fertilizer, which minimizes the use of agrochemicals, and none of the families needed to buy fertilizer, since all of them had their own production of bovine manure or obtained it from third parties. The practice of composting also helped the families not to need a large amount of fertilizer, because the compost helps to make the soil suitable for planting. In addition, the reuse water is rich in nutrients, making it a way to fertilize the soil with natural fertigation (Handam et al. 2021). However, in eight systems they presented water wastage problems, such as in the rainy season when the plants do not need to be irrigated and the system does not stop producing water, although they could use the reuse water on the larger plants in the living fence, which can withstand more water. Even, for the families that had a risk of saturation of the agrosystem filter, they could build another filter (Machado & Rovere, 2018), operating in parallel, to divide the large volume of water and avoid overload. Component maintenance was the indicator that resulted in the worst situation, as families could not keep up with the optimal frequency for each component, directly affecting the functioning of the system as a whole, decreasing its performance and efficiency (Beneduce et al., 2017).

The decline in the performance of the systems over the monitored period can be explained by the fact that in the first campaign the systems were new and actually working as they should, but as time went by, the families stopped following the recommended protocols, with frequent care and maintenance, such as changing the filter material and cleaning the grease box in the correct time periods for the good functioning of the treatment. The low performance for the removal mainly of Sodium (37%), Nitrate (33%) and BOD (11%), can compromise the nutrition and toxicity of plants (Almeida, 2010; Bortolini et al., 2018), but as expected, also described in wastewater from Sewage Treatment Plants, BOD was not improved by the system (Moura et al., 2020).

The efficiency of the systems when having average optimal removal for the parameters TSS, BOD, TB and QOD, indicated efficient retention process of coarser solids by the grease box and filtration of solids of smaller diameter by the biological filter. The average TSS removal efficiency of 91.44% is above other studies that also analyzed the performance of graywater treatments for non-potable reuse, by different methods, such as Mergulhão & Emery (2011) who found 86% removal; Feitosa et al. (2011) with 80 to 88%; and Rocha (2013) with 71% removal.

The removal of BOD meets the requirements of CONAMA Resolution No. 430 of 2011 for effluent discharge, which determines a minimum removal of 60%. Compared with other similar studies on effluent treatment for reuse purposes, the averages follow a similar pattern of organic matter removal. Dombroski et al. (2013) studied the treatment efficiency of a system using the same method applied in this case, being in the state of Rio Grande do Norte, and found an average removal of BOD and QOD of 78 and 74%, respectively, in the year 2009, and 81% in the year 2010 for the two indicators. Still in Rio Grande do Norte, Feitosa et al. (2011) evaluated the performance of graywater treatment systems for agricultural reuse, but with another methodology applied, with removals ranging between 64 and 93% for BOD and between 50 and 83% for QOD.

The result of the low removal efficiency of E. coli by the agrosystems is worrisome, since the World Health Organization (WHO) requires that, for irrigation, a high removal efficiency of concentration of parasitic forms in the effluent sewage treatment that reaches between 90% and 99.8% is necessary (Santos et al. 2012). When evaluating each analysis, it is found that within a sample N of 57 calculated efficiencies, 16 achieved removal equal to or above 90%, and that the lowest value found was negative, of -547.06%. This also occurred in the study of Dombroski et al. (2013), who found the lowest value of E.coli removal as negative, and explain that it probably occurred due to the influence of contamination from external agents of pollution to the treatment system, noting that the units studied by them, follow the same conception and technology related to this work. In this study, the averages were 48.2% in 2009 and 95.3% in 2010 of efficiency in removal of this pathogen.

CONCLUSION

This study on the evaluation of rural agroecosystems that use reuse water from greywater for agricultural purposes has brought important knowledge to the context of sustainability, especially for Brazilian states inserted in the semi-arid region of the Northeast, which need initiatives and ways to provide for living with drought, that promote, besides quality of life, the social inclusion of minority social groups, through the integrated implementation with other sectoral public policies, such as health, housing and environment.

However, these actions present a significant potential of socioeconomic and environmental contribution to the farming families. The proposal presented, besides reusing water, which is scarce for several reasons, and solving the problem of environmental pollution by gray water, provides the production and cultivation of food for families, promoting food security for this portion of the population.

On the other hand, the results indicate that although the availability of water for agriculture has improved due to the reuse systems, the families still complain of suffering from a lack of water during dry periods, even if in smaller proportions. This shows that drought and difficulties with water resources will always exist in this region, but this population needs to coexist and always be supported by technologies and public policies that provide a better coexistence with the semi-arid region and its conditions.

Finally, with the analysis of the selected indicators, it is concluded that the agroecosystems, in general, are being and are sustainable between a regular and good state, that is, the majority of the indicators presented satisfactory results above the intermediate score of 2.00, but none reached the ideal state of 3.00, nor 2.50.

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