Development and application of a rural water supply assessment tool in Brazil

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Abstract
The objective of this paper is to develop and to apply a rural water supply systems (WSS) assessment tool to typical cases in Brazil. The methodology developed comprises the following steps: (1) a brief description of the tools previously developed; (2) combination and adaptation of previously developed tools employing a multicriteria approach; (3) data gathering and simulation of real cases; (4) application of the developed tool to typical cases in Brazil. Adaptations were done and they consisted of some indexes modifications (safety of drinking water and rural WSS structural condition), inclusion of the TOPSIS Method for selection of the adaptive solution, and consideration of local expertise information for definition of weights. Some of modified indexes were those for conditions of water reservoirs and water distribution network. It can be concluded that the Brazilian rural WSS showed operational and maintenance problems. The developed tool was considered as an useful decision support to the planning of the Brazilian rural WSS.

Keywords: rural households; technical assessment; water problem

Introduction
The process operation is one of the main points of an operator of sanitation, since it is directly tied to its core competency. Its management is critical to success and to ensure continued market presence. The vast majority of carriers of sanitation services operate their systems without a methodology that enables the tracking and monitoring of their processes, as well as the process of decision making. The lack of an operation methodology brings some consequences such as the low quality of products and services provided by the service provider of sanitation services, resulting in the unavailability of water to the user and therefore public health problems. The incidence of problems in water supply systems or the unavailability of drinking water can lead to risky behavior such as poor water conditioning and looking for water supplies inadequated for consumption. This is especially true for rural areas, where the population, in most cases, does not have any solution to the system of rural water supply (rural WSS).

This paper describes a toolset for assessment and application to rural WSS in remote areas. In the following sections of the paper, the section 1 presents an introduction. Section 2 presents a brief review of some relevant literature. Section 3 describes the methodology. Section 4 describes the results and section 5 describes and shows the conclusions of paper.

Review of related research
In the current section of the paper, a brief description of some paper related to the subject evaluation rural WSS are present.

Sauer (2003) development a research is focused on the efficiency of water supplying infrastructure in rural areas. A cross-sectional data set was collected with respect to water companies in rural areas of East and West Germany. After formulating partial performance indexes, the relative cost efficiency was estimated by a stochastic frontier analysis. Due to this analysis, first (preliminary) results show that the technical efficiency in the (rural) water sector can be improved by up to 45% with the same technology and the same hydrological and supplying characteristics. No significant effect on suppliers' inefficiency by regional location was found. Economies of scale are verified for the sample suggesting the realization of efficiency gains by the expansion of the average supplying area. Assumed explicit negative effects on firms' efficiency by the existing legal framework of the water sector are hence empirically confirmed. The analysis of the determinants of public funding reveals that there is no significant influence of operational efficiency on the decision about funding by public institutions. Finally it is shown that firms in East Germany enjoy an easier access to public funds, regardless how efficient their operations are.

Amaral *et al*. (2003) assessed the sanitary quality of drinking water in rural farms through counts of microbiological indicators. A total of 180 drinking water samples from sources, reservoirs and water consumption sites were collected in 30 rural farms located in the northeast region of the state of São Paulo, Brazil. The most probable number of total coliforms, *Escherichia coli* and mesophilic microorganisms were determined. Also, the presence of protection measures for water supplies was verified. The study results showed that 90.0% of drinking water samples from sources, 90.0% from reservoirs, and 96.7% from water consumption sites, collected during the rainy season, and 83.3%, 96.7% and 90.0% of samples collected in dry season were below the quality control standards for drinking water. The conclusions indicated that drinking water in rural farms was considered a potential human health threat. Preventive measures for protecting water sources and water treatment would be necessary to significantly reduce the occurrence of waterborne diseases.

Keshavarzi *et al*. (2006) investigated the relationships between water consumption and rural household activities are determined by comparing a snapshot of water consumption with rural household behavior of low, medium and high water consumers. In addition, the factors affecting water consumption in rural households are also determined. The data for this study were collected from a survey of 653 rural households in 33 villages of Ramjerd area, Fars Province, in southern Iran, using a simple random sampling technique. The daily water consumption data for a 5-year period (1999–2004) were used. Results of the study revealed that the daily average water consumption for the area was found to be 121.7 L per person per capita per day (Lpcd). Water consumption was also found to be significantly correlated with explanatory variables such as ‘‘household size’’ and ‘‘age of household’s head’’. Finally, the results of discriminant function analysis showed that in rural households, garden size, greenhouse size, and garden watering times per month with tap treated water are associated with water consumption.

Azevedo (2006) showed the experience related with the water supply system implantation in the indigenous villages of Nova Esperança, Vila Nova II and Nossa Senhora de Nazaré of the ethnic group Sateré-Mawé, located in the region of the Marau river, district of Maués, Amazon State, Brazil. These water supply systems began operating in 1998 and were modified to aggregate other elements linked to the cosmology of that people and that had not been observed in the initial project. The study demonstrated the importance of understanding the indigenous culture which allows the effective participation in the discussions of the several phases of the project in order to facilitate the acceptance and the correct utilization of the adopted solution.

Results of the study conducted by Somalia Water and Land Information Management (SWALIM) in rural area Somalia, are present by Muthusi *et al*. (2007). SWALIM conducted a desk study assessment to determine the water supply situation in rural Somalia. The assessment was done in three regions: Puntland, Somaliland and South-Central Somalia. The assessment involved review and analysis of available data and literature on existing water supplies. Interviews were conducted in Nairobi, Puntland and Somaliland with key players in the Somali water sector. Field visits to some water points were also made by two consultants, one in Puntland and another in Somaliland, to see the condition of the water sources and to interview operators and water users. The findings of the assessment were similar in many aspects for the three regions, with only slight differences between them. In Puntland, the assessment concluded that: (1) shortages in water supply are not only a function of limited water sources, but also as a result of frequent breakdown of the sources; (2) rural communities in Puntland try to cope with water shortages by minimizing the amount of water usage per day and in many cases this compromises hygiene standards, creating some health risks; (3) the Puntland authority is unable to support the much-preferred community-based water supply projects, making people more reliant on external donors. The conclusions for Somaliland were as follows: (1) shallow well aquifers in rural Somaliland are not well developed and many of the shallow wells dry up in the Jilaal and Hagaa seasons; (2) there are many sources with water unsuitable for human consumption, but locals use them either out of ignorance or because they do not have an alternative; (3) hygiene facilities in rural Somaliland are limited, the people live in poor sanitary conditions and water availability is explained in terms of quantity, not quality. Conclusions for South–Central Somalia include: (1) South-Central Somalia is much advantaged in terms of surface water resources compared to other regions of the country; (2) use of water resources for economic development is inefficient due to lack of a water policy; (3) the Somali community, due to high scarcity quantity of water available is more important than quality and this has contributed to a large extent to frequent outbreaks of cholera and other waterborne diseases in the region.

Methodology

The methodology developed comprised the following steps: (1) a brief description of the tools previously developed; (2) combination and adaptation of the tools previously developed employing a multicriteria approach; (3) data gathering and simulation of real cases; (4) application of the developed tool to the typical cases in Brazil.

The brief description of the tools previously developed (1) comprised the description of the tool developed by Rietveld *et al*. (2009). For step (2) the tools previously developed were combined and adapted for the traditional multicriteria approach, by reviewing patterns of local water quality, inclusion of the TOPSIS Method (for selection of the most adaptive solution) and also local expertise (for definition of weights). The tool of assessment of rural WSS was developed in Microsoft Excel worksheet. For step (3) data gathering and simulation, the necessary data were gathered from the local operators of rural WSS and local community. The hard data were simulated from literature review about local community. In step (4), the developed tool was applied to typical cases in Brazil, using data gathered and simulating input to the developed tool, and the results were analyzed.

Results

The tool for technical assessment of rural WSS developed by Rietveld *et al*. (2009) is based on four criteria, namely availability, capacity, continuity and condition. Availability pertains to the adequacy of the source in terms of quantity and quality of the water that can be obtained from it. The availability fails when quantity and quality are below the standard for drinking water supply. The capacity is the adequacy of the storage, transport and distribution to supply water to the community. Unacceptable capacity will typically arise when a village grows in size, per capita demand and population to the point where a previously good system will begin to fail in its inadequacy. Continuity is the consistency whereby water is conveyed from the source to the water point. Water supply can be interrupted when a pump is broken, pipes are damaged or taps cannot be opened, among others. The condition of a system would reveal more about the expected lifetime than durability because it takes into account the external factors which play a major role in rural and poor communities. The condition is the status of the system in terms of its serviceability. The criteria are quantified by indexes, which allow comparison of performance of different rural WSS. Some of the variables that relate to accounts for the water losses in the rural WSS, turbidity in water, total coliforms in water, required water flow distribution, among others. Additional information about the tool, equations and variables involved, can be found in the article.

The adaptation of the tool developed by Rietveld et al. (2009) basically consisted of modifications to the criteria of water availability and condition of the rural WSS criteria for inclusion of a social nature. Whereas the rural WSS systems, its classification as alternative water supply, and that the Brazilian standards of water quality (Decree 518/2004 of the Ministry of Health) for such a situation, there is the necessity of including some water quality variables (e.g., residual chlorine free and color in water). For the criteria condition there is need to insert some components (e.g., conditions of the residential reservoir). A criterion of social character, disposition of the population to cooperate with actions to improve the rural WSS, was inserted into the tool. A method of multicriteria decision support, the TOPSIS method, was also available at tool for evaluating the rural WSS in order to help select the best alternative workaround for the rural WSS. The equations considered in each of the criteria are presented in sequence.

The availability index (I_{av}) is defined by Equations 1, 2, 3, 4, 5, 6, 7 and 8.

$$I_{av,quant} = \frac{\eta \times V_{month} \times 1000}{30 \times \left((N \times D)_{sp} + (N \times D)_{yc} + (N \times D)_{hc} \right)} \leq 1 \quad (1)$$

$$I_{av,qual} = \varepsilon_1 . I_{pH} + \varepsilon_2 . I_{NTU} + \varepsilon_3 . I_{TC} + \varepsilon_4 . I_{CL} + \varepsilon_5 . I_{CO} \leq 1 \quad (2)$$

$$I_{pH} = \begin{cases} e^{\mu 1.(pH-7)} & se\ pH \geq 7{,}0 \\ e^{\mu 2.(7-pH)} & se\ pH < 7{,}0 \end{cases} \quad (3)$$

$$I_{NTU} = e^{-\mu 3.NTU} \quad (4)$$

$$I_{TC} = e^{-\mu 4.TC} \quad (5)$$

$$I_{CL} = \mu_5 . CL + \mu_6 \quad (6)$$

$$I_{TC} = e^{-\mu 7.CO} \quad (7)$$

$$I_{av} = \alpha_1 . I_{av,quant} + \alpha_2 . I_{av,qual} \quad (8)$$

Where: N is the number of people with access to a standpipe or hand pump (sp), yard connection (yc) or house connection (hc), D is the minimum demand related to one the mentioned (in Lppd), V_{month} is the monthly production (in m^3/month), η accounts for the water losses in the rural WSS, μ_i are constants depending on the allowable values in the drinking; and, ε_i are weighing factors, where $\Sigma\mu_i = \Sigma\varepsilon_i = 1$; pH is the water hydrogenic potential; NTU is water turbidity; TC is water total coliforms; CL is concentration free chlorine in the water; CO is color in water.

The capacity index is composed by four indexes: (1) pumping capacity from the source (I_{pump}); (2) storage volume to overcome differences between demand and pumping capacity and calamities (I_{res}); distance of water points from consumers ($I_{wp,dens}$); and, number of water points with too rates ($I_{wp,funct}$). The capacity index (I_{cap}) is defined by Equations 9, 10, 11, 12 and 13.

$$I_{pump} = \frac{Q_{pump}}{Q_{demand}} \leq 1 \tag{9}$$

$$I_{res} = \frac{V_{res}}{Q_{demand} \times T_{res}} \leq 1 \tag{10}$$

$$I_{wp,dens} = \sum \frac{\rho_{wp}}{\rho_{wp,\min}} \leq 1 \tag{11}$$

$$I_{wp,funct} = \frac{N_{wp,good}}{N_{wp,total}} \leq 1 \tag{12}$$

$$I_{cap} = \beta_1 . I_{pump} + \beta_2 . I_{res} + \beta_3 . I_{wp,dens} + \beta_4 . I_{wp,funct} \tag{13}$$

Where: Q_{pump} is the actual pumping capacity (in m^3/h); Q_{demand} is the water flow for distribution, including losses in the system (in $m^3.h^{-1}$), V_{res} is the installed reservoir (in m^3), T_{res} is the required minimum storage time (in h), ρ_{wp} is the actual water point (wp) density (in wp/km^2); $\rho_{wp,min}$ is the minimum required water density (in wp/km^2), $N_{wp,good}$ is water point with a sufficient flow rate, $N_{wp,total}$ is the total number of water points and β_i are weighing factors, where $\Sigma\beta_i = 1$.

Two indexes characterized the criterion of continuity: the number of hours per day of unplanned interruption of water supply to the households ($I_{hours,day}$) and the number of days per month without unplanned water supply ($I_{day,month}$). The continuity index (I_{cont}) is defined by Equations 14, 15 and 16.

$$I_{day,month} = e^{-\lambda \times \left(N_d - N_{d,\max}\right)} \leq 1 \tag{14}$$

$$I_{hours,day} = \frac{T_{\sup}}{T_{\sup,\min}} \leq 1 \tag{15}$$

$$I_{cont} = \gamma_1 . I_{day,month} + \gamma_2 . I_{hours,day} \tag{16}$$

Where: T_{sup} is the supply per day (in h); $T_{sup,min}$ is the minimum, predetermined supply time per day (in h); Nd is the number of days per month without water, while water was available; $N_{d,max}$ is the maximum allowable number of days per month without water, and γi are weighing factors, where $\Sigma\gamma_i = 1$; λ is factor depends on local circumstances and insights.

The elements considered to index of condition are: damage and/or leakage of the tap (I_{tap}); damage and/or leakage of the residential reservoir ($I_{house,res}$); and, damage and/or leakage of the water net ($I_{water,net}$). The condition index (I_{cond}) is defined by Equations 17, 18, 19 e 20.

$$I_{tap} = \frac{N_{tap,good}}{N_{wp,total}} \tag{17}$$

$$I_{house,res} = \frac{N_{house,res,good}}{N_{house,res,total}} \tag{18}$$

$$I_{water,net} = \begin{cases} 0,1 & if \quad \text{conditions are bad} \\ 0,5 & if \quad \text{conditions are reasonable} \\ 1,0 & if \quad \text{conditions are good} \end{cases} \tag{19}$$

$$I_{cond} = \delta_1 . I_{tap} + \delta_2 . I_{house,res} + \delta_3 . I_{water,net} \tag{20}$$

Where: $N_{wp,total}$ is the total number of water points in the community; $N_{ta,good}$ is the number of taps that are is good state; $N_{house,res,good}$ is the number of residential reservoir in good state in the community; $N_{house,res,total}$ is the total number of residential reservoir state in the community; and, δi are weighing factors, where $\Sigma\delta_i = 1$.

Two indexes characterized the criterion of social character. The first index is the percent of family that shows good acceptance for the practice of water conservation ($I_{acceptance}$), and the second is the percent of family that perform existing best-practice for water conservation ($I_{good,practice}$). The social index (I_{social}) is defined by Equations 21, 22 and 23.

$$I_{acceptance} = \frac{N_{family,acceptance}}{N_{family,total}} \quad (21)$$

$$I_{good,practice} = \frac{N_{family,practice}}{N_{family,total}} \quad (22)$$

$$I_{social} = \kappa_1 . I_{acceptance} + \kappa_2 . I_{good,practice} \quad (23)$$

Where: $N_{family,acceptance}$ is the number of family that have good acceptance the practice of water conservation in the community; $N_{family,total}$ is the total number of family in the community; $N_{family,practice}$ is the number of family that current existing best-practice; κ_i is of weighing factors, where $\Sigma\delta i = 1$.

To the judge the different rural WSS in the selected, the following schema was used: bad 0.00 < I < 0.50; fair 0.50 < I < 0.75; sufficient 0.75 < I < 0.90; and, good 0.90 < I < 1.00.

Having the knowledge of the characteristics of rural WSS, alternatives for tool improvement can be proposed. When looking for this, multicriteria decision support methods are useful. In this way, the TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution), developed by Hwang and Yoon (1981), was coupled to the same environment as the assessment tool of rural WSS. The use of TOPSIS has appeals as simplicity (ease of application) and the mode how it faces a decision problem by comparing two hypothetical situations: ideal and undesirable. This approach is based on the technique of order preference by similarity to ideal solution. The ideal solution is defined as that have a smaller distance (or highest similarity) compared to ideal solution (A+) and also holds the greatest distance (lower similarity) in relation to undesirable solution (A–). This method is rational and comprehensible and evaluate the decision matrix in 6 steps: (1) normalized matrix representing the relative performance of alternatives, (2) create standardized and weighted matrix, (3) provides an ideal solution with the aggregation process, (4) computes a n-dimensional measure of separation, by using the Euclidean distance for all alternatives, (5) calculates the relative closeness to the ideal solution, and (6) orders the alternatives according to decreasing values. The Equations 24, 25 and 26 present the distances equations.

$$d(A+) = \left[\sum_{i=1}^{n} w_i^h \left| \frac{f_i^* - f_i(x)}{f_i^* - f_i^{**}} \right|^h \right]^{\frac{1}{h}} \quad (24)$$

$$d(A-) = \left[\sum_{i=1}^{n} w_i^h \left| \frac{f_i(x) - f_i^{**}}{f_i^* - f_i^{**}} \right|^h \right]^{\frac{1}{h}} \quad (25)$$

$$d(A+, A-) = \frac{d(A-)}{d(A+) + d(A-)} \quad (26)$$

Where: d(A+) is the distance between the ideal solution vector and the vector of the studied case; w_i is the weighing of the considered criteria, $\Sigma w_i = 1$; f_i^* is the value of the ideal solution in the criteria i; $f_i(x)$ is the value is the performance of the studied alternative in the criteria I; f_i^{**} is the value of the undesirable solution in the criteria I; h is the parameter of sensibility verification, the value is 1, 2 and ∞; i is identification of the criteria in the study; d(A–) is the distance between the undesirable solution vector and the vector of the study case; d(A+,A–) is the distance among the ideal solution vector and the undesirable solution vector, and the vector the studied case.

In this research, suggested criteria include: cost of investment (i = 1); reducing water consumption (i = 2); reduction of water losses (i = 3); technological level (i = 4); and acceptability of the population (i = 5). The alternatives designed to improve the rural WSS are closely related to characteristics of each case. However, when considering the main design elements of rural WSS (water extraction in deep wells, disinfection by chlorine solution, elevated water storage reservoir, distribution water net and household connections), presented by Azevedo (2006), and the hypothesis that there are problems of maintenance and operation of rural WSS, some alternatives suggested for improvement comprises the following: (1) implementation of a government program for qualification of people for operation and maintenance of rural WSS, (2) replacement of the chlorination treatment system for a chlorination system at home in order to simplify system operation, and (3) replacing the rural WSS for a system composed by surface water use and slow filtration. As mentioned earlier, these alternatives must consider the specificities of each case and are presented merely as possible suggestions.

The Figures 1a, 1b, 1c and 1d shows the water collection and water supplying infrastructure in rural WSS.

(a)

(b)

(c)

(d)

Figure 1. Community Cinturão Colina Verde, in Cuiabá city, Mato Grosso state: water collection in house (a); reservoir of the community (b); pipes of water distribution (c); water net in contact with wastewater (d)

In Table 1 are presented the results for some real cases in Brazil. Table 2 summarize the indexes results for the case studies.

Table 1. Some indexes of five rural WSS in Brazil

Some data input	A	B	C	D	E
Number of households*	426	125	90	131	115
Volume reservoir (in m^3)*	30	5	2	5	5
Total number of water points*	420	25	22	26	23
Conditions of water net*	bad	bad	bad	bad	bad
Total number family*	107	36	30	43	38
pH	7,50	5,30	5,00	5,00	5,50
NTU	1,0	3,0	2,0	0,5	4,0
TC (in NMP.100mL^{-1})	56	0	0	0	0
CL (in mg.L^{-1})	0,0	0,0	0,0	0,0	0,0
CO (in mgPt.L^{-1})	5	2	2	1	2
Water supply per day (in h)	8	3	2	3	3
Pumping capacity (in $m^3.h^{-1}$)	8	2	1	3	3

*Data obtained by a questionnaire in the study sites, by simulation and literature review

A is the community Cinturão Colina Verde, in Cuiabá city, Mato Grosso state; B is the community Ipixuna, in Humaitá city, Amazonia state; C is the community Paraisinho, Humaitá city, Amazonia state; D is the community Paraisinho Grande, Humaitá city, Amazonia state; and, E is the community São Miguel , Humaitá city, Amazonia state

Table 2. Results of the technical assessment of five rural WSS in Brazil

Criteria	A	B	C	D	E
Availability index (I_{av})	0,6507	0,8617	0,6656	0,7708	0,9875
Capacity index (I_{cap})	0,9181	0,9187	0,9427	0,9481	0,9324
Continuity index (I_{cont})	0,1990	0,0500	0,0334	0,0500	0,0500
Condition index (I_{cond})	0,3936	0,1479	0,2333	0,5500	0,4167
Social index (I_{coop})	0,3150	0,1583	0,5167	0,8209	0,4079

A is the community Cinturão Colina Verde, in Cuiabá city, Mato Grosso state; B is the community Ipixuna, in Humaitá city, Amazonia state; C is the community Paraisinho, Humaitá city, Amazonia state; D is the community Paraisinho Grande, Humaitá city, Amazonia state; and, E is the community São Miguel , Humaitá city, Amazonia state

We also made the prioritization of the performance criteria according to respective indexes and weight of each criterion. The assumption made for the priority was that the lower the performance criterion the higher the priority actions to improve rural WSS and the greater the weight the higher the priority for improvement in the criterion, according to Equation 27. Table 3 shows the values of the criteria weights obtained by consulting the public and experts.

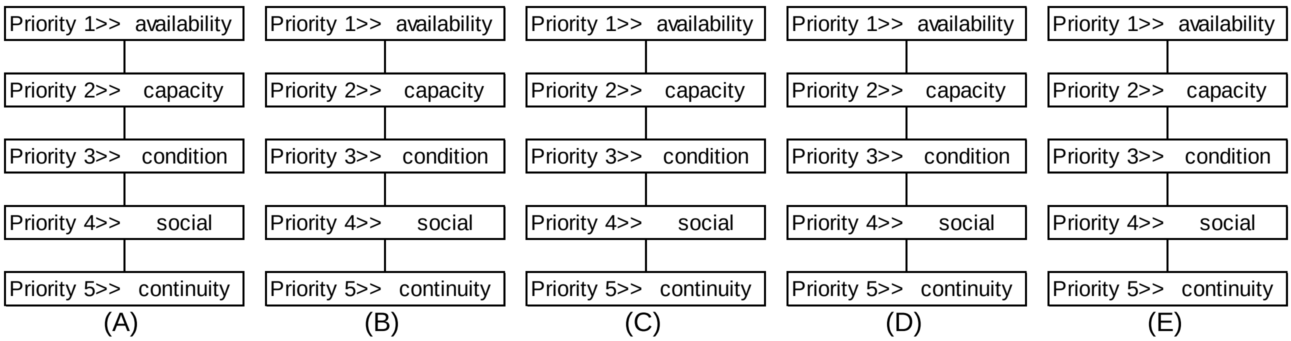
Table 3. Criteria weighing (average value)

Criteria	Weigh
Availability index (I_{av})	0,55
Capacity index (I_{cap})	0,20
Continuity index (I_{cont})	0,01
Condition index (I_{cond})	0,20
Social index (I_{coop})	0,04

Figures 1a, 1b, 1c, 1d and 1e show the prioritization criteria to improve the conditions of rural WSS for each of the cases studied.

$$P = \begin{cases} I_{av} \times \upsilon_1 \\ I_{cap} \times \upsilon_2 \\ I_{cont} \times \upsilon_3 \\ I_{cond} \times \upsilon_4 \\ I_{coop} \times \upsilon_5 \end{cases} \quad (27)$$

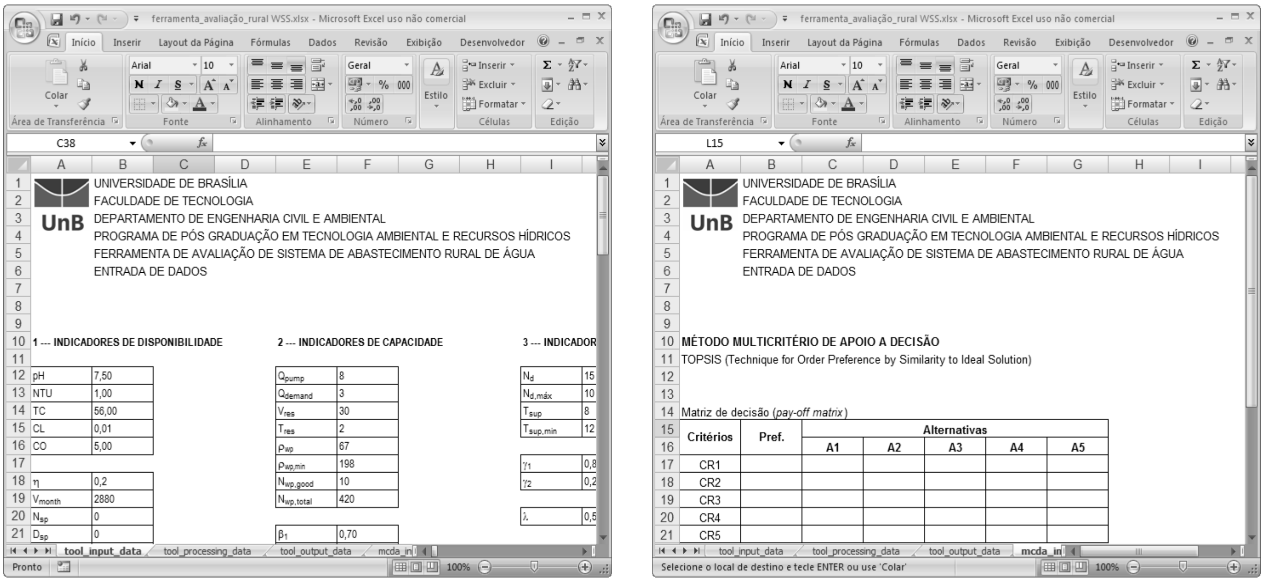
Where: υ_1 is weighing availability index; υ_2 is weighing capacity index; υ_3 is weighing continuity index; υ_4 is weighing condition index; and, υ_5 is weighing social index. The sum of the weights should be equal $\Sigma\upsilon_i$=1.



A is the community Cinturão Colina Verde, in Cuiabá city, Mato Grosso state; B is the community Ipixuna, in Humaitá city, Amazonia state; C is the community Paraisinho, Humaitá city, Amazonia state; D is the community Paraisinho Grande, Humaitá city, Amazonia state; and, E is the community São Miguel , Humaitá city, Amazonia state
Figure 2. Prioritization criteria

According to Figure 2, the model adopted for prioritizing criteria showed slight sensitivity. There are still similarities among the cases, as shown in the Table 2, and the main problems are related to the continued supply of water.

The tool was developed in an environment Excel (spreadsheet program from Microsoft) in order to make it accessible, easy to use. Figures 3a and 3b show data screens of the tool developed in Excel environment. The developed tool allows to obtain the values of criteria, after data entry, and also helps the decision-making, using the TOPSIS method. The tool is capable do receive the input of five alternatives and five criteria of selection. However, a larger number of alternatives and criteria can be easily added.



(a) (b)

Figure 3. Assessment tool: data entry screen for evaluation (a); entry screen data for decision making (b)

Conclusion

A tool for assessment system of rural water supply was developed and applied to some rural communities in Brazil, more specifically in communities of Mato Grosso and Amazonas states.

The tool has some improvements over the tool previously developed by Rietveld et al. (2009), including the insertion of the TOPSIS method to improve the selection of actions to enhance community water systems, implementation of models in Excel spreadsheet, and the proposition in order to prioritize criteria of rural WSS.

There is still need for improvement of the developed tool, especially with regard to the prioritization of the criteria for rural water supply systems. The more accurately collection of data points to better results.

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References

Amaral, L.A.; Nader Filho, A.; Rossi Junior, O.D.; Ferreira, F.L.A. (2003). Água de consumo humano como fator de risco à saúde em propriedades rurais. Revista de Saúde Pública, 37(4), 510–514.

Azevedo, R.P. (2006), Sistemas de abastecimento de água: a experiência nas aldeias Sateré-Mawé do Rio Marau no município de Maués - Amazonas, in proceedings of the 3º Seminário Internacional de Engenharia de Saúde Pública, in Fortaleza, BRA.

Hwang, C.L.; Yoon, K. (1981). Multiple attribute decision making. Methods and applications. A State of the Art Survey. New York: Springer-Verlag.

Keshavarzi, A.R.; Sharifzadeh, M.; Haghighi, A.A.K.; Amin, K.; Keshtkar, S.; Bamdad, A. (2006). Rural domestic water consumption behavior: A case study in Ramjerd area, Fars province, I.R. Iran. Journal Water Research, 40, 1173–1178.

Ministério da Saúde. (2004), Portaria MS nº. 518/2004, available at: <http://portal.saude.gov.br/portal/arquivos/pdf/portaria_518.pdf>. [Accessed 29 April 2010].

Muthusi, F.M.; Mahamud, G.; Abdalle, A.; Gadain, H.M. (2007). Rural Water Supply Assessment, Technical Report No-08, FAO-SWALIM, Nairobi, Kenya. [on line]. <available at: <http://www.faoswalim.org/ftp/Water_Reports/Cleared/W-08%20Rural%20Water%20Supply%20Assessment.pdf>. [Accessed 29 April 2010].

Rietveld, L.C.; Haarhoff, J.; Jagals, P. (2009). A tool for technical assessment of rural water supply systems in South Africa. Physics and Chemistry of the Earth, 34, 43–49.

Sauer, J. (2003). The Efficiency of Rural Infrastructure – Water Supply in Rural Areas of Transition. [on line]. available at: <http://ideas.repec.org/p/wiw/wiwrsa/ersa03p463.html>. [Accessed 04 July 2010].