THE ENGINEERING PROJECT ORGANIZATION JOURNAL, 2016
VOL. 6, NOS. 2–4, 92–103
http://dx.doi.org/10.1080/21573727.2016.1241243

Taylor & Francis
Taylor & Francis Group

Exploring the use of social network analysis to inform exit strategies for rural water and sanitation NGOs

Jeffrey Paul Walters

Department of Civil Engineering, Universidad Diego Portales, Santiago, Chile

ABSTRACT
While integrated management schemes often improve resolution of technical issues with rural water and sanitation (WatSan) infrastructure, the challenges they can present are more complex. One example is the proper communication between stakeholders, a challenge that is magnified when the service is constructed and managed by a non-governmental organization (NGO) that later leaves the management structure. This study investigates an approach to visualize and quantitatively evaluate how communication between stakeholders influences resolution efforts, using social network analysis (SNA). The methods employed here are demonstrated with a case study in the municipality of Darío, Nicaragua, where a large WatSan NGO is planning its exit strategy. Survey data were used to construct weighted social networks representing the efficacy of communication links and pathways on both water and sanitation service resolution in Darío. SNA was then used to evaluate the potential implications of the NGO's disengagement on communication networks, and thus, future resolution activities for both service types. Analysis of communication networks for water and sanitation service resolution afforded distinct recommendations for proper NGO disengagement tailored to each service type. Thus, this study demonstrates a novel application of SNA to visualize and analyse the influence of communication on rural WatSan service resolution activities, and presents an adaptable and robust tool WatSan practitioners can use to inform their exit strategies.

ARTICLE HISTORY
Received 3 June 2016
Accepted 20 September 2016

KEYWORDS
Exit strategies; social network analysis; rural water service resolution; Nicaragua; developing countries

1. Introduction

A contemporary and increasingly prevalent belief within the international rural water and sanitation (WatSan) development sector is that community-based management (CBM) schemes are ineffective at providing sustained access to services. This is a shift from a long-held philosophy that communities should be solely responsible for maintaining their WatSan technology, typically by way of a community water committee (CWC). In contrast, studies have highlighted numerous cases where CWCs found it difficult, if not impossible to maintain the long-term functioning of their WatSan services, whether due to the lack of technical skills (Lockwood *et al.*, 2002; Harvey and Reid, 2004; Lockwood and Smits, 2011), a lack of community capacity or willingness to pay for the service (Whittington, 1990; Harvey and Reid, 2004; Whittington *et al.*, 2009), or the presence of destructive conflicts within the community (Carter *et al.*, 1999; Harvey and Reid, 2004; Carter and Rwamwanja, 2006). Indeed, many experts contend that CBM is not a sustainable management scheme without reliable external backing from an entity such as a non-governmental agency (NGO), to provide technical, managerial, and financial support to communities (Lockwood *et al.*, 2002; Komives *et al.*, 2008; Whittington *et al.*, 2009; Lockwood and Smits, 2011; Schouten *et al.*, 2011). However, one does not necessarily exclude the other. Many experts agree that CWCs should be the party responsible for performing basic and routine maintenance of their WatSan services, as well as ensuring the system is properly operated and used by community members (Harvey and Reed, 2004; Musonda, 2004; Gine and Perez-Foguet, 2008; Montgomery *et al.*, 2009; Schweitzer and Mihelcic, 2012; Silva *et al.*, 2013). Thus, the sector is rapidly progressing towards an integrated management philosophy that combines CBM and some form of external support, which Baumann (2006) calls 'community management plus', where the plus indicates pairing CBM with a consistent form of external support (Hutchings *et al.*, 2015). Overall, the proponents of this scheme claim integrated management more aptly facilitates effective 'resolution' of technical issues with WatSan infrastructure, thereby promoting long-term service functionality (Improve International, 2014).

While in many cases integrated management schemes improve resolution efforts, the challenges they can

CONTACT Jeffrey Paul Walters jeffrey.walters@udp.cl

present are more complex than those based purely on CBM (Ramalingham *et al.*, 2008; Amadei, 2015; Neely, 2015). These challenges are a result of variation in the type and quality of WatSan technology installed, continuity of support by the implementing agency or organization, and the associated influences these aspects can have on proper communication, and thus coordination, between service stakeholders (Carter *et al.*, 1999; Brikké, 2000; Chambers, 2005; Rietveld *et al.*, 2007; Montgomery *et al.* 2009; Lockwood and Smits, 2011; Ramirez *et al.*, 2012; Kaboyashi *et al.*, 2014). Regarding the latter, Carter *et al.*, (1999) mention effective resolution requires that, 'communication lines between community and the back-stopping agency [external entity] need to be clear, and response times need to be rapid' (p.9). Kaboyashi *et al.* (2014) support this point, stating that clear communication within the community itself, as well as with outside communities, is a key component for the 'collective action' (p.1) needed to enable effective collaboration and knowledge exchange regarding a particular technical issue, and its resolution. Koboyashi *et al.* (2014) and Dwi Ari *et al.* (2014) go further to demonstrate a clear connection between communication links and pathways between water service stakeholders and the efficacy of water service resolution. Studies also indicate the WatSan technology type and sophistication can greatly influence the extent of external support required in any integrated management scheme, and the associated channels of communication required to support long-term resolution efforts (Harvey and Reed, 2004, 2006, Kaboyashi *et al.*, 2014). This, in turn, requires easy access to tools, materials, and stakeholder know-how necessary to perform routine maintenance and repair (Narayan, 1995; Carter *et al.*, 1999; Lockwood *et al.*, 2002; Harvey and Reed, 2006; Rietvelt *et al.*, 2007; Gine and Perez-Foguet, 2008; Godfrey *et al.*, 2009; Jones *et al.*, 2012). Lastly, communication within an integrated management scheme is often further complicated, or even hampered, in the common case where the service is constructed and managed by a NGO that later disengages and places the responsibility of future service resolution on the remaining stakeholders (Brikké, 2000). A key aspect of successful disengagement is retaining the integrity of adequate communication channels between various stakeholders, to seamlessly enable the continued operation and maintenance of WatSan services well after the NGO exits the service site. This requires the disengaging NGO to develop an exit strategy that, in part, establishes a healthy network of communication to facilitate future resolution activities (Gardner and Greenblot, 2005; ACF, 2007).

Unfortunately, while literature points to the need for NGOs to establish robust communication channels for WatSan service resolution before disengagement, there is a dearth of practical approaches NGOs can utilize to assess and evaluate existing communication networks. This gap is addressed here by developing a practical technique that uses social network analysis (SNA) to evaluate the potential impacts of NGO disengagement on the vital communication channels that facilitate effective WatSan service resolution. The author posits that SNA affords a powerful quantitative accompaniment to traditional qualitative approaches (e.g. case studies, ethnography) by offering a concrete interpretation of stakeholder influence and importance related to their position and interaction within communication networks (Wasserman and Fraust, 1994; Scott, 2000; Borgatti, 2005; Schoenenberger and Schenker-Wicki, 2014).

Based on the aforementioned challenges with integrated management schemes, the aspects of interest investigated here with SNA were (i) communication links and pathways between WatSan service stakeholders and their influence on resolution efforts, (ii) the influence technology, problem and repair type has on communication links and pathways, and (iii) the potential implications of NGO disengagement on resolution communication and efficacy. The associated questions that served as a guide for these research efforts were:

> *RQ1:* Who do stakeholders communicate with to resolve issues with WatSan services?
>
> *RQ2:* How does the problem or technology type influence this communication?
>
> *RQ3:* How important is each service stakeholder in terms of their influence on communication links and pathways for effective service resolution?

The sections that follow outline the steps taken to answer these research questions. These steps are demonstrated herein through a case study performed in the municipality of Darío, Nicaragua, where a large WatSan NGO is planning its exit strategy. The findings afforded through these methods are used to inform recommendations for how the disengaging NGO can best fortify existing communication channels and practices to mitigate issues with WatSan service resolution in Darío, and to highlight the utility of using SNA as a tool to facilitate exit strategy planning activities.

2. Methods

This section presents the mixed methods approach used to develop social networks to visualize and analyse communication between WatSan service stakeholders in Darío, Nicaragua. A methodology based on SNA was chosen for its ability to quantitatively infer how communication links and pathways influence resolution efforts. In particular, social networks were analysed to evaluate stakeholder importance (RQ3) based on their positioning (RQ1) within the social network (Wasserman and Fraust, 1994; Scott, 2000). Survey-based interviews were used to gather the data necessary to build, analyse, and interpret networks of stakeholder communication and importance. The data were first used to interpret the significance and meaning of network links on effective communication. This was accomplished by performing statistical association analysis of aspects of stakeholder communication, including communication links based on the perceived effectiveness of the resolution efforts, the timeliness of repair (Carter *et al.*, 1999), and frequency of service breakdowns. Social networks pertaining to both water and sanitation services were then analysed to evaluate stakeholder communication and resolution efficacy, in particular, the potential impacts of the NGO's disengagement on communication links and pathways. A description of each of these steps is presented below.

2.1. Data collection

The municipality of Darío, Nicaragua, was selected as the study site because it presented a case where a significantly large WatSan NGO was in the process of disengaging from an existing integrated WatSan service management scheme. The disengaging NGO (from now on referred to as NGO1) has been involved with WatSan projects in Darío for over 25 years. The municipality of Darío has a population of roughly 41,000 habitants, a large percentage of whom live within 160 rural communities located outside of the town center. To date, NGO1 has installed water and sanitation systems in 68 and 78 communities in Darío, respectively. While NGO1 intentionally keeps minimal post-construction involvement with communities, dedicated community educators within the organization maintain contact with CWCs to ensure that proper management of the system is taking place. In the case of a catastrophic system failure, NGO1 endeavours to provide the necessary funds or resources to fix the system.

While over the years various types of WatSan technologies have been installed in Darío by the government and other external organizations and agencies, the two primary forms of water service technologies are rope pump and electric pump systems, while the predominant sanitation technology are ventilated improved pit (VIP) latrines, or simple improved pit latrines (Figure 1).

Data collection followed an embedded multi-case study scheme, with the embedded unit of analysis set at the community level within the larger case study context treated at the municipality level (Yin, 2002). The sparse distribution of communities located along steep and poorly maintained dirt roads required sampling to be conducted 'quasi-randomly', entailing choosing a set of communities (about 120) that existed along viable roads, and then stringing together randomly selected travel routes. The WatSan service problem was identified at the community level, where the source of resolution communication would thus originate, as CWCs would conceivably be the first to know if a technical issue were to arise. Data collection entailed conducting survey-based interviews with WatSan service stakeholders guided by both open and closed response survey questions. For water services, six distinct stakeholder groups were interviewed. At the community level, CWC members (between three and five interviewees) were interviewed. At the municipality level, interviews took place with the local government (three interviewees), NGO1 (five interviewees), the material and construction provider (two interviewees), two ministry-run water service providers: ENACAL (Nicaragua Water and Sewer Company, one interviewee) and MARENA PINCHE (the Ministry of Environmental and Water Resources, two interviewees), and the national provider of electricity, Union Fenosa (one interviewee). In the case of sanitation services, four stakeholder groups were interviewed: the CWC, government, NGO1, and an in country NGO, from now on referred to as NGO2 (one interviewee).

Of the 40 communities sampled, 34 had well-sourced water supply systems: 22 were in the form of electrical pumps, 12 were rope pumps, and the remaining 6 communities were composed of those using unprotected sources, and alternative water supply technologies such as gravity-fed systems. For sanitation systems, 29 of the 40 communities had improved sanitation infrastructure in the form of VIP latrines installed by NGO1. The designation of an 'improved' sanitation system was based on the World Health Organization's definition as one that separates human excreta from human contact, in the form of either basic pit or VIP latrines (WHO/UNICEF JMP, 2015).

To gather the necessary data to build social networks, stakeholders were asked questions pertaining to their communication with other project stakeholders in the event of WatSan service issues, where CWCs in particular were asked to indicate the most common technical issue. Typically, SNA treats communication as binary connections (network 'edges'), between actors (network 'nodes'), where the network structure is of primary interest (Wasserman and Fraust, 1994; Scott, 2000). In this study, however, an important structural characteristic was not only the existence of a communication link (edge) between stakeholders (nodes), but also the efficacy of the communication itself (edge weight); where within

Figure 1. The three primary WatSan technologies in Darío. Rope and electric pumped wells (left and middle, respectively) and ventilated improved pit latrine (right).

the weighted network the communication link was intended to represent a level of efficacy for resolution. As such, in addition to asking interviewees who they spoke with in the event of a problem, they were also prompted to categorically score the time it took to typically resolve the problem, the frequency in which the WatSan technology typically breaks down, and to present their opinion on the utility or efficacy of the communication with said stakeholder. For time, a higher edge score was given for a shorter duration of time to resolve the issue, where the scores were (4) – days, (3) – weeks, (2) – months, and (1) – years/never. For frequency of break downs, a higher score was given for a lower frequency, where the scores were (5) – hardly ever, (4) – yearly, (3) – monthly, (2) – weekly, (1) – daily. For the stakeholder's opinion on efficacy, a higher score was given for a more favourable level of efficacy from (4) – very good, (3) – good, (2) – mediocre, and (1) – not good at all. In this way, it was possible to construct weighted networks representing aspects of WatSan resolution efficacy.

2.2. Data analysis: statistical association of communication links

Before creating and analysing social networks, statistical associations were conducted to interpret statistical dependence between communication links based on the aforementioned aspects of resolution efficacy (i.e. perceived efficacy, time to resolve issue, and frequency of breakdowns). In addition, statistical association was performed to evaluate if communication links were dependent on technology or problem type (RQ2), or on the stakeholder that initially installed the service (an intuition based on field observation). These pertinent categories for statistical association analysis resulted in three types of link–node relationships using both nominal (e.g. frequency of breakdown) and ordinal (e.g. the particular stakeholder) categorical variables. Type 1 relationships were used to identify dependencies between communication and overall resolution efficacy based on the perceived (opinion-based) efficacy indicated by the stakeholders, the time it typically took to resolve the issue, and the frequency of breakdowns (i.e. ordinal variables). Type 2 relationships were used to identify dependencies between communication and technology, the nature of the problem, and on the entity who initially installed the service. Type 3 relationships were used to evaluate dependencies between the technology itself on the time and frequency of repairs. Evidence of a statistical association was based on the null-hypothesis (H_0), which indicated that there was no statistically significant relationship regarding the interpreted meaning of the communication link, based on the Pearson's chi-square test. An overview of these statistical tests is listed below:

Type 1: communication and resolution efficacy

- *Communication efficacy:* Stakeholder communication and the resulting (perception-based) efficacy of the resolution effort; H_0: Communication and the perceived efficacy of resolution effort are statistically independent.
- *Communication time:* Stakeholder communication and the resulting time it takes to resolve the issue; H_0: Communication and the amount of time it takes to resolve the issue are statistically independent.
- *Communication frequency:* Stakeholder communication and the resulting frequency of break downs;

H_0: Communication and the frequency of break downs are statistically independent.

Type 2: communication and technology, problem, and installer

- *Communication technology*: Stakeholder communication given the type of technology; H_0: Communication and the type of technology are statistically independent.
- *Communication problem:* Stakeholder communication given the nature of the problem; H_0: Communication and the problem type are statistically independent.
- *Communication installer:* Stakeholder communication given the entity that initially installed the technology; H_0: Communication and who installed it are statistically independent.

Type 3: technology – repair time and breakdown frequency

- *Technology time*: Type of technology and the associated time it took to repair; H_0: Technology and the amount of time it takes to resolve the issue are statistically independent.
- *Technology frequency*: Type of technology and the associated frequency of break downs; H_0: Technology and frequency of breakdown are statistically independent.

Evaluation of these three types of link–node relationships followed the method for statistically analysing associations between pairs of categorical variables described by Agresti and Finlay (1997). Pearson's chi-square (χ^2) test for significance was used because the comparison of categorical variable pairs in this case was composed of both nominal and ordinal variables, and other similar tests (i.e. gamma, Kendall's tau-b or tau-c, Spearman's rho-b and rho-c, and Somers'-d) generally require both categorical pairs to be ordinal (Agresti and Finlay, 1997). The process of analysing each relationship type used the following five steps, per Agresti and Finlay (1997):

1. Constructing a contingency table for each pairing of categorical variables for each link–node relationship type
2. Constructing an expected frequency table (f_e) with each cell being the expected frequency based on each cell of the contingency table, where for each cell:
   $f_e = (\text{column total/total sample size})\ (\text{row total})$
3. Calculating the chi-squared statistic using the tables in steps 1 and 2,
   where $\chi^2 = \sum^{(f_o - f_e)^2}/f_e$, and f_o is the relative cell in the contingency table
4. Calculating the p-value for the chi-square test of independence using the chi-squared score and the degree of freedom (df) for each pairing's contingency table, where $df = (\text{num row} - 1)\ (\text{num col} - 1)$.
5. Comparing the p-value with the desired level of significance α set at 0.05 to evaluate statistical significance such that a p-value $< .05$ rejects the null-hypothesis and assumes statistical dependence.

2.3. Data analysis: social networks

Identifying and weighing communication links between stakeholders varied in difficulty, form, and subjectivity. Identifying and link weights between CWCs and the other stakeholders was a relatively trivial and straightforward task, since each of the CWC stakeholders clearly indicated the stakeholder they communicated with given an issue, and the time, frequency of the repair, and perceived efficacy associated with this communication, using the scoring rubrics mentioned previously. However, this process was more complicated and nuanced when talking with external support stakeholders, as their responses were less clear regarding their lines of communication. Thus, it was often necessary to interpret communication links based on their responses. The quote below from a government stakeholder presents an exemplar of these types of stakeholder communication interpretations in [brackets]. In this interview, the government evaluated the communication link as resulting in a 'good' (network edge weight 3) resolution effort that typically took a 'week' (network edge weight 3) to complete

> As the municipal government, we have a diagnostic and a method to receive information on all of the problems with water and sanitation faced by the communities. We compare these problems with the budget that we have, and prioritize the repairs that we do. In the case where the municipal government is not able to do the repairs themselves, or if they do not have the necessary funds, we ask for help from ENACAL, MARENA PINCHE, and local organizations [NGO1, and NGO 2]. If there are problems with the electricity, we contact the electric company and they solve the problem. [Union Fenosa]

Once communication links were ascertained between all of the stakeholders, a three-columned weighted edge-list (origin–target–weight) was built and imported into Gephi version 0.9.1 (Gephi, 2015). Communication networks were built in Gephi to supplement the evaluation of stakeholder importance by providing a visual backdrop with which to convey the research findings. Network edges (links) were treated as 'directed' (i.e. arrows instead of lines), as the direction of communication between stakeholders was a meaningful attribute of network structure. This allowed for the evaluation of communication links and their strengths as they 'flowed' from each stakeholder to the other. While the positioning of nodes within social networks is structurally arbitrary, two nodal distributions within Gephi were chosen in particular to visualize the geospatial relationship between stakeholders (GeoLayout), and to pull apart and visualize each node, link, and node grouping (Fruchterman Reingold's force-directed algorithm).

Weighted centrality measures based on these network diagrams were used to identify stakeholder importance through identifying direct and indirect communication links. For direct communication links, degree-in and degree-out centrality were calculated to measure direct communication with and from each stakeholder, respectively. For indirect links (i.e. pathways), betweenness centrality was calculated to score stakeholder importance based on their capacity to bridge shortest (and therefore, most efficient) paths of communication between other stakeholders (Freeman, 1977; Borghatti, 2005). An additional network analysis based on the Freeman centralization (network centrality) was used to supplement these 'actor'-level centrality comparisons by showing the proportion of importance from the most important stakeholder compared to the other stakeholders (Freeman, 1979).

Because it is not possible to calculate centrality for weighted networks in Gephi, each score was instead calculated in R-Project using the package 'tnet' (Opsahl *et al.*, 2010). Centrality scores were calculated using Equations 1–3, for degree and betweenness centrality, and overall network centralization, respectively. In Equations 1 and 2, α represents a tuning parameter that can be used to balance the importance placed on links and their weights (Opsahl *et al.*, 2010). In this study, α was taken as 0.5, meaning the weights and links were considered equally important in calculating centrality.

Weighted degree (in or out) centrality

$$C_D^{w\alpha} = k_i \times \left(\frac{s_i}{k_i}\right)^{\alpha}, \quad (1)$$

where k_i represents the traditional formula for degree centrality of a binary network, $C_D(i) = \sum_j^N x_{ij}$, where i is the node of interest and j are all the other nodes; s_i represents the traditional formula for weighted degree centrality of a binary network; $C_D^w(i) = \sum_j^N w_{ij}$, where i is the node of interest and j are all the other nodes and N represents the total number of nodes.

Weighted betweenness centrality

$$C_B^{wa} = \sum_{j \neq i \neq k} \frac{g_{jk}^{w\alpha}(i)}{g_{jk}^{w\alpha}}, \quad (2)$$

where $g_{jk}(i)$ represents the number of shortest paths between nodes j and k that are enabled by passing through node i, g_{jk} represents the total number of shortest paths that exist between nodes j and k and w represents the weight of the link.

Network centrality

$$C_B = \frac{\sum_{i=1}^N [C'_B(p^*) - C'_B(p_i)]}{\max \sum_{i=1}^N [C'_B(p^*) - C'_B(p_i)]}, \quad (3)$$

where $C_{B,D}$ is the normalized score for betweenness or degree-based centralization, $C'_{B,D}(p^*)$ is the most central node based on betweenness or degree centrality, $C'_{B,D}(p_i)$ is betweenness or degree centrality for each node in the network, $\max \sum_{i=1}^{n} [C'_{B,D}(p^*) - C'_{B,,D}(p_i)]$ is the maximum network centrality based on betweenness, for a wheel or star $= N^3 - 4N^2 + 5N - 2$, used to normalize the network centrality score and N is the total number of nodes.

3. Results and discussion

In this section, insights gained through the previously outlined methods are summarized and interpreted by first looking at the results from the statistical association analysis of communication links. Using the information from this link analysis, the social networks for water and sanitation are analysed to identify the most important stakeholders using the previously mentioned centrality analyses. Finally, key interpretations of these results are used to inform potential implications of NGO1 disengagement to inform recommendations for how NGO1 can best exit the municipality of Darío.

3.1. Association analysis: link meaning and significance

Of the eight statistical tests for link–node associations performed for each of the three types of categorical relationships mentioned in the previous section, two were statistically significant for water services and one was statistically significant for sanitation services, while link–node relationships, based on technology and problem type, were found to be insignificant. A summary

Table 1. Analysis of statistically significant link–node associations.

Water				
Association	n	χ^2	df	p
Communication|Technology	34	7.75	5	.1711
Communication|Problem	34	1.78	4	.7763
Communication|Installer	38	22.07	5	.0005[a]
Communication|Efficacy	37	21.18	15	.1312
Communication|Time	37	34.48	15	.0029[a]
Communication|Frequency	38	15.72	20	.7338
Technology|Time	33	2.75	3	.4318
Technology|Frequency	33	3.08	4	.5445
Sanitation				
Association	n	χ^2	df	p
Communication|Technology	–	–	–	–
Communication|Problem	29	4.74	3	.1919
Communication|Installer	–	–	–	–
Communication|Efficacy	29	32.72	12	.0011[a]
Communication|Time	–	–	–	–
Communication|Frequency	29	5.66	12	.9320
Technology|Time	–	–	–	–
Technology|Frequency	–	–	–	–

Note: – indicates a statistical association was not possible.
[a]Reject H_0 at $\alpha = 0.05$.
.

of the analyses, for all eight statistical associations for both water and sanitation, are shown in Table 1.

For water services, the majority of problems ($n = 34$) were malfunctioning pumps or pump system infrastructure ($n = 20$), or water shortages due to diminishing ground water sources ($n = 14$). As these were the principle issues in the communities sampled, statistical association testing only considered these problem categories. Statistically significant relationships were found between CWC communication and the amount of time it took to resolve the issue (Communication|Time, p .0029), and the influence the initial installer had on communication (Communication|Installer, p .0005). Some of the non-significant association pairs included communication based on the type of problem (Communication|Problem, $p = .7763$), the association of communication and the frequency of technical issues (Communication|Frequency, $p = .7338$), and to a lesser extent, the association of communication based on technology type (Communication|Frequency, $p = .1711$), thereby answering RQ2 regarding the influence of problem or technology type on stakeholder communication. Thus, communication links (weighted edges) within the social networks for water service resolution were based on, and interpreted as, resolution timeliness.

For sanitation, the only statistically significant relationship existed between CWC communication and the level of efficacy (Communication|Efficacy, $p =$ .0011), where the other associations, especially communication and frequency of breakdowns (Communication|Frequency, $p = .932$), were either not significant or applicable. The negligible variability in technology-types, along with the high percentage of services that had been installed by NGO1, made any statistical comparisons between sanitation technology on communication or service functionality irrelevant. As a result, Table 1 shows that viable comparisons existed only for communication and perceived efficacy, frequency, and problem. In addition, a viable calculation of the statistical association between communication and the time to resolve the service issue was not possible, as each CWC indicated a score of 2 (months), regardless of the stakeholder communication link. Given these results, communication links (weighted edges) within the social network for sanitation services were relate to perceived efficacy of resolution.

Table 2. Weighted centrality score ranks for water (time, 44 nodes) and sanitation (efficacy, 33 nodes).

Water (time)					
Betweenness[a]		Degree-in[b]		Degree-out[c]	
Government	187	Government	33	NGO1	24
NGO1	125	Provider	26	Provider	24
Provider	42	NGO1	25	Government	8
ENACAL	26	ENACAL	18	–*	–*
MARENA	20	MARENA	7	–*	–*
Sanitation (efficacy)					
Betweenness[d]		Degree-in[e]		Degree-out[f]	
Provider	291	NGO1	52	Provider	66
NGO1	182	Provider	25	NGO1	56
Government	100	–*	–*	Government	6
–*	–*	–*	–*	–*	–*
–*	–*	–*	–*	–*	–*

Note: Network centrality: [a]0.101; [b]0.017; [c]0.012; [d]0.284; [e]0.047; [f]0.062.
*Indicates scores that are negligible or 0.

3.2. Social network analysis: stakeholder importance

Based on the findings from the statistical association analyses, resolution efficacy as a result of communication links (and their weights) were interpreted as timeliness of resolution for water services, and as perceived efficacy for sanitation services. These two networks are visually represented in Figure 2, which presents networks displayed with GeoLayout, and the Fruchterman Reingold's force-directed algorithm. The weights of directed arrows are displayed as bolder lines having the highest weight. To aptly display the connection between the different stakeholders, only the external support entities are indicated on these graphs, where the non-labeled nodes represent the communities sampled.

The ranked weighted centrality scores for each network are shown in Table 2. For water services, the government was found to be the most central based on weighted degree-in centrality (33) and betweenness centrality (187). Based on the assumption that these weighted social networks offer insight into overall

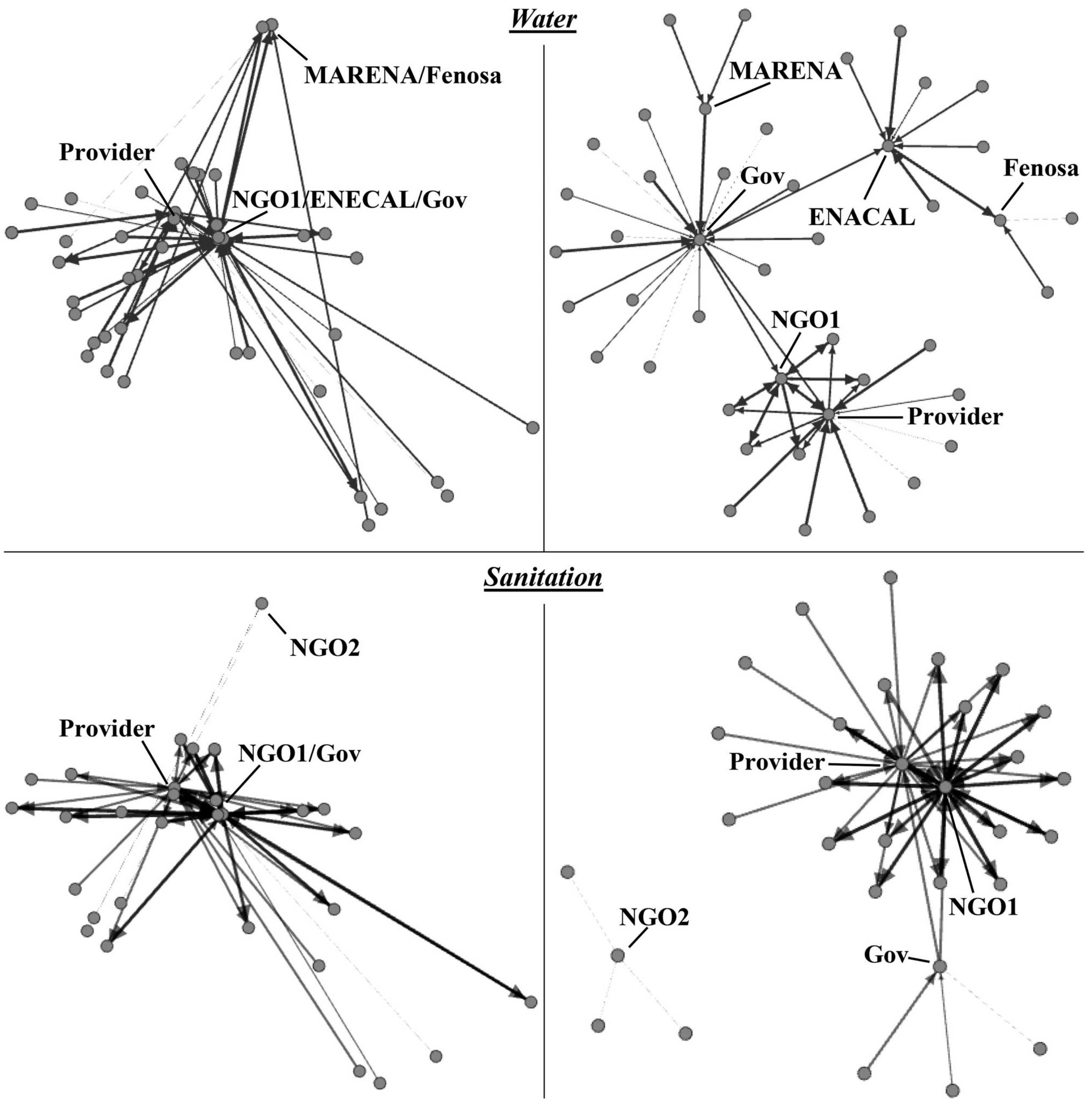

Figure 2. Social network graphs for water (top) and sanitation communication (bottom); left: GeoLayout; right: Fruchterman Reingold's force-directed algorithm

stakeholder influence on resolution efficacy demonstrates that the government is the most influential in the resolution of water service issues. Overall, the government, NGO1 (betweenness 125), and provider (betweenness 42) were found to most efficiently (shortest paths) form communication pathways between the communities and external sources. Figure 2 (top right) shows that NGO1 was an influential player in bridging communication between the government and the provider, and in a similar way, shows how the ministry agencies ENACAL and MARENA PINCHE are tightly connected to the municipal government. However, ENACAL and MARENA PINCHE were found to have moderate influence on resolution efforts overall, as seen with their low scores for degree and betweenness centrality in Table 2.

For sanitation, the provider had the highest betweenness and degree-out scores (291 and 66, respectively), meaning that they were significantly more influential in executing resolution efforts. These are intuitive results, as NGO1, being the primary installer of the technology, would logically be the first touchpoint by the community (degree-in score 52), later transitioning communication and resolution efforts to the construction provider, and the communities they serve.

Network centrality scores differed significantly between water and sanitation networks, as summarized on the bottom of Table 2. Because the water network has a larger number of nodes (44) compared to the sanitation network (33), it is expected that it would have a proportionately lower network centrality score compared to the sanitation network. However, network centrality analyses reveal a three, four, and sixfold difference in network centrality scores between water and sanitation networks based on betweenness, degree-in, and degree-out centrality scores, respectively. This finding reinforces the assertion that for sanitation services one particular stakeholder – in this case the material provider – has a comparatively far greater influence on communication within the resolution network.

3.3. Implications and recommendations

Key recommendations exist for NGO1 based on the implications of the findings presented above. A summary of these findings, their unique implications on future resolution efforts for both water and sanitation services, and associated recommendations for how NGO1 can minimize potentially adverse impacts from their disengagement, are shown in Table 3.

For water services, the results imply both positive and negative impacts on future resolution efforts as a result of NGO1's disengagement, based on the existing capacity for resolution with the current service stakeholders, and the implications of their relative importance on resolution efficacy. The degree-in and betweenness centralities for water service social networks (based on timeliness) showed that a high level of direct communication already exists with the government, who also provides the greatest level of indirect influence on resolution activities. This result proves favourable for the future impact of NGO1's disengagement on resolution efforts, implying the most influential communication channels for resolution operate independent from NGO1. Unfortunately, despite having the greatest influence on resolution efforts, the data showed, in general, that government-led water service resolution was slower (months) than the majority of the other stakeholders (days and weeks). This is shown visually in Figure 2, where the majority of the network edges entering the government node are fainter lines. While conceivably the hope of NGO1 is to hand off responsibility of water service management to local stakeholders, these findings show that the government may not be able to provide the timeliest resolution. Potentially the provider, who has a relatively high betweenness and degree centrality score for timeliness, could fill, or reinforce, this role. However, as can be seen in Figure 2, and as is shown in the betweenness centrality scores in Table 2, the tightly connected communication between NGO1 and the provider could fracture the necessary communication channels that enable beneficial communication links between the communities, provider, and government. This suggests that NGO1 should ensure that communication channels are adequately bridged. One approach could be to develop a transparent communication protocol directing who CWCs should talk in the event of an unmanageable service issue, highlighting the important connection between the government and provider. Additionally, because NGO1 appeared to have the highest scores for timeliness (see Figure 2), implies NGO1 should convey best practices and community interaction protocol to all remaining stakeholders – including ENACAL and MARENA PINCHE who were found to work closely with the government – before fully disengaging.

For the sanitation service resolution efforts (based on stakeholders' perceived efficacy), the findings are somewhat similar, and potentially more encouraging, than those found for water service resolution. In this case, the provider was found to be most influential on effective sanitation service resolution overall (betweenness 291, degree-out 66), also receiving generally high scoring of efficacy from the CWCs, as shown in Figure 2. This implies that the provider is already a critical part of the communication network for service resolution, independent from NGO1. Compared to the NGO1 (degree-in 52), however, the provider receives considerably less communication from the CWCs (degree-in 25), once again highlighting the need for NGO1 to promote clear lines of communication from the CWCs to the provider. Additionally, an evident gap exists regarding current and future government involvement (betweenness 100, degree-out 6) in sanitation infrastructure installation and resolution. Thus, NGO1 should confirm the government's plans with sanitation infrastructure management before executing their exit strategy, and see if it is possible to encourage improvements in their existing programmes.

In summary, these results suggest that NGO1 plays two distinct roles for water and sanitation, thereby necessitating unique strategic disengagement processes and timelines for both services. For water, NGO1 appears to be assuming an advisory role to the other key service stakeholders, indicating that disengagement could be phased out through systematically decreasing their level of consultation over time. Disengagement for sanitation services, however, would require a longer and more involved process involving a systematic transfer

Table 3. Summary of findings, implications, and recommendations for NGO1.

	Findings	Implications	Recommendations for NGO1
Water	The majority of CWCs communicate with government despite initial installation by NGO1	NGO1 disengagement impacts on existing communication networks could be less pronounced	Further encourage and facilitate the communication between CWCs and government
	Highest betweenness centrality based on timeliness: Government, followed by NGO1/provider	Government is most influential in bridging communication and resolution efforts, however, this resolution is generally executed in a less timely fashion than the other external stakeholders	Fortify existing communication and knowledge exchange between the government and provider
		The link between NGO1 and provider could be broken when NGO1 disengages	Encourage more effective resolution practices in government policy
	Highest degree-in centrality based on timeliness: Government followed by the provider	The government and provider are communicated with most often when communities have water service issues	Promote existing communication channels between the CWC and government and provider
	Highest degree-out centrality based on timeliness: NGO1 followed by the provider	Most communication with CWCs takes place from NGO1 and provider	Encourage communication from government and provider to CWCs
Sanitation	Highest betweenness centrality based on perceived efficacy: provider followed by NGO1	Provider most effectively bridges communication and resolution efforts	Ensure CWCs maintain primary contact with the provider in the event of a service issue Build capacity of the local government
	Highest degree-in centrality based on perceived efficacy: NGO1 followed by the provider	NGO1 is communicated with most often given issues with sanitation services	Promote CWC communication with the provider Build capacity of the local government
	Highest degree-out centrality based on perceived efficacy: provider followed by NGO1	Provider is in contact most with the other stakeholders	Promote existing communication channels between the provider and CWCs Build capacity of the local government

of knowledge and communication to project stakeholders, and combining these activities with capacity building of the local government. Unequivocally, these recommendations imply different timelines; requiring NGO1 to stay longer in Darío to finish with sanitation services after finishing their involvement with water services.

4. Conclusions

This study investigated a means to evaluate the impacts of NGO disengagement on WatSan service resolution, focusing specifically on the impacts of disengagement on the communication channels that facilitate effective resolution of technical issues. The methodological approach chosen to accomplish the research objective was the creation and analysis of social networks representing stakeholder communication links and pathways associated with resolution efforts. To demonstrate the research methods, a case study was conducted on rural WatSan technology resolution in Darío, Nicaragua, where a major NGO (NGO1) is in the process of leaving the service site.

Through the analysis of communication networks for service resolution, it was possible to offer recommendations to NGO1 by addressing the research questions proposed at the start of this paper related to the structure of WatSan resolution communication networks (RQ1), the influence problem and technology type have on communication (RQ2), and the importance of each stakeholder for resolution efforts based on their connectivity within the network (RQ3). In particular, analysis of social networks showed that the current communication links and pathways between WatSan service stakeholders in Darío are moderately well suited for NGO1's disengagement. For water services, analysis of social networks showed the majority of communities, represented by community water committees (CWCs), contacted the government in the event of water service issues, and indicated that the government was the most influential in orchestrating water service resolution efforts overall. However, based on the CWC assessment of timeliness overall, the government was generally less effective when compared to the other stakeholders. In addition, NGO1 was found to be a vital bridge between the government and material and construction provider. For sanitation services, network analyses showed the crucial influence of the provider on resolution activities, and the need for NGO1 to encourage improvements in the administrative capacity of the government to bolster future resolution efforts following NGO1's departure. These findings demonstrate the need for NGO1 to encourage best practices for government-led service resolution, especially regarding timeliness, conjointly strengthening the existing connection between CWCs, providers, and ministry agencies. This could be accomplished through the formation of a communication protocol that outlines the communication process, along with preferred best practices to be executed throughout the resolution cycle. These recommendations align with theory and practice in the sector related to the general importance of post-construction support communication (Carter *et al.*, 1999; Harvey and Reid, 2004), and the need to develop and fortify communication channels and best practices between internal and external project stakeholders (Brikké, 2000; Gardner and Greenblot, 2005; ACF, 2007; Montgomery *et al*., 2009). Overall, the quantitative identification of the most influential stakeholders through evaluating their direct and indirect communication channels using SNA (centrality analysis), informed unique exit strategy recommendations tailored to water and sanitation services regarding how NGO1 can fortify stakeholder communication before leaving Darío. In addition, the use of network graphs to display the interaction of communication provided a visual backdrop to interpret and make sense of these results. As such, this study demonstrates a useful and novel application of SNA to visualize and analyse important communication links and pathways for rural WatSan service resolution.

It is unlikely that the recommendations presented here are generalizable in other project or programme contexts. For example, NGOs that stay for a shorter time (i.e. three to five years), use a different form of management strategy, or operate within a different cultural and socio-economic context, would invariably imply a distinct array of recommendations based on differently structured social networks. In highlighting these common distinctions, however, demonstrates the merits of this approach, as it offers an adaptable methodology NGOs and practitioners can use to plan exit strategies that facilitate effective resolution efforts through the formation of proper communication networks between permanent WatSan service stakeholders.

Acknowledgments

The author would like to extend his sincere appreciation and gratitude to, Henry Torres, Gregory Rivers, Rob Bell, and the El Porvenir field staff for helping gather the data necessary to conduct this research.

Disclosure statement

No potential conflict of interest was reported by the author.

Funding

This work was supported by the University of Colorado Boulder Beverly Sears Graduate Student Research Grant.

References

Action for Hunger (ACF). (2007) *How to make WASH projects sustainable and successfully disengage in vulnerable contexts: a practical manual of recommendations and good practices based on a case study of five ACF-IN water, sanitation and hygiene projects*. ACF – International Network.

Agresti, F. and Finlay, B. (1997) *Statistical Methods for the Social Sciences*, 3rd edn, Prentice Hall, Inc., Upper Saddle River, NJ.

Amadei, B. (2015) *A Systems Approach to Modeling Community Development Projects*, Momentum Press LLC, New York, NY.

Baumann, E. (2006) Do operation and maintenance pay? *Waterlines*, **25**(1), 10–12.

Borgatti, S.P. (2005) Centrality and network flow. *Social Networks*, **27**, 55–71.

Brikké, F. (2000) *Operation and Maintenance of Rural Water Supply and Sanitation Systems, a Training Package for Managers and Planners*. IRC International Water & Sanitation Centre, WHO, Water Supply & Collaborative Council, Operation & Maintenance Network.

Carter, R. and Rwamwanja, R. (2006) *Functional Sustainability in Community Water and Sanitation: A Case Study From South-West Uganda*, Tearfund, Teddington.

Carter, R., Tyrrel, S. and Howsam, P., (1999) Impact and sustainability of community water supply and sanitation programs in developing countries. *Chartered Institution of Water and Environmental Management*, **13**, 292–296.

Chambers, R. (2005) *Ideas for Development*, Routledge, New York, NY.

Dwi Ari, I.R., Jeong, H., Matsushima, K. and Kobayashi, K. (2014) *Network Analysis of Community Based Water Management. Chapter 12: Community Based Water Management and Social Capital*, IWA Publishing, London.

Freeman, L.C. (1977) A set of measures of centrality based on betweenness. *Sociometry*, **40**(1), 35–41.

Freeman, L.C. (1979) Centrality in social networks: conceptual clarification. *Social Networks*, **1**(3), 215–239.

Gardner, A. and Greenblot, J.E. (2005) What we know about exit strategies, practical guidance for developing exit strategies in the field. C-SAFE, A Product of the C-SAFE Regional Learning Spaces Initiative, Sept 2005 (CARE, CRS, World Vision, ADRA, USAID).

Gephi. 2015. Gephi.org.

Gine, R. and Perez-Foguet, A. (2008) Sustainability assessment of national rural water supply program in Tanzania. *Natural Resources Forum*, **32**, 327–342.

Godfrey, S., Freitas, M., Muianga, A., Amaro, M., Fernandez, P. and Mosies, S. (2009) Sustainability Check: A monitoring tool for sustainability of rural water supplies, in *34th WEDC International Conference*, Addis Ababa, Ethiopia.

Harvey, P.A. and Reed, R.A. (2004) *Rural Water Supply in Africa: Building Blocks for Hand Pump Sustainability*. Water, Engineering and Development Centre, Loughborough University, Loughborough.

Harvey, P.A. and Reed, R.A. (2006) Community-managed water supplies in Africa: sustainable or dispensible? *Community Development Journal*, **42**(3), 365–378.

Hutchings, P., Chan, M.Y., Cuadrado, L., Ezbakhe, F., Mesa, B., Tamekawa, C. and Franceys, R. (2015) A systematic review of success factors in the community management of rural water supplies over the past 30 years. *Water Policy*, **17**, 963–983.

Improve International. (2014) *Guidelines for Resolution of Problems with Water Systems*. Improveinternational.org/resolution. Available at https://improveinternational.files.

wordpress.com/2014/10/resolution-of-problems-with-water-systems-full-report-10-12-14.pdf (accessed 9 January 2015)

Jones, S., Anya, A., Stacey, N. and Weir, L. (2012) A life-cycle approach to improve the sustainability of rural water systems in resource-limited countries. *Challenges*, **3**, 233–260.

Kobayashi, K., Syabri, I., Dwi Ari, I.R. and Jeong, H. (2014) *Community Based Water Management and Social Capital*, IWA Publishing, London.

Komives, K., Akanban, B., Thorston, R., Tuffuor, B., Wakeman, W., Larbi, E., Bakalian, A. and Whittington, D. (2008) Post-construction support and the sustainability of rural water projects in Ghana, in *33rd WEDC International Conference*, Accra, Ghana.

Lockwood, H., Bakalian, A. and Wakeman, W. (2002) Assessing sustainability in rural water supply: the role of follow-up support to communities. *Literature Review and Desk Review of Rural Water Supply and Sanitation Project Documents*, Britain.

Lockwood, H. and Smits, S. (2011) *Supporting Rural Water Supply: Moving Towards a Service Delivery Approach*. Practical action publishing. The Schumacher Centre, Warwichshire, IRC and Aguaconsult.

Montgomery, M.A., Bartram, J. and Elimelech, M. (2009) Increasing functional sustainability of water and sanitation supplies in rural Sub-saharan Africa. *Environmental Engineering Science*, **26**, 1017–1023.

Musonda, K. (2004) Issues regarding sustainability of rural water supply in Zambia, master's thesis, The University of South Africa.

Narayan, D. 1995. *The Contribution of People's Participation: Evidence From 131 Rural Water Supply Projects*. Environmentally Sustainable Development Occasional Paper Series No. 1, The World Bank, Washington, DC.

Neely, K. (2015) Complex adaptive systems as a valid framework for understanding community level development. *Development in Practice*, **25**(6), 785–797.

Opsahl, T., Agneessens, F. and Skvoretz, J. (2010) Node centrality in weighted networks: generalizing degree and shortest paths. *Social Networks*, **32**, 245–251.

Ramalingham, B., Jones, H., Toussaint, R. and Young, J. (2008) *Exploring the Science of Complexity: Ideas and Implications for Development and Humanitarian Efforts*. Working Paper 285. Overseas Development Institute, 111 Westminster Bridge Road, London.

Ramirez, M.C., Plazas, J., Torres, C., Silva, J., Caicedo, C. and Gonzalez, M. (2012) A systemic framework to develop sustainable solutions to rural communities in Columbia. Case Study: Ingenieros sin Fonteras Columbia. *Systemic Practice and Action Research*, **25**, 95–116.

Rietveld, L., Haarhoff, J. and Jagals, P. (2007) A tool for technical assessment of rural water supply systems in South Africa. *Physics and Chemistry of the Earth*, **34**, 43–49.

Schouten, T., Fonseca, C., Lockwood, H. and Moriarty, P. (2011) *Taking A Service Delivery Approach to Monitoring Water Supply in Low Income Areas and Implications for the Joint Monitoring Programme*, Water Services That Last, The Hague.

Schweitzer, R. and Mihelcic, J. (2012) Assessing sustainability of community management of rural water systems in the developing world. *Journal of Water, Sanitation and Hygiene*, **2**(1), 20–30.

Schoenenberger, L. and Schenker-Wicki, A. (2014) Can system dynamics learn from social network analysis?, in *System Dynamics Society Conference 2014*, Delft, Netherlands.

Scott, J. (2000) *Social Network Analysis: A Handbook*, 2nd edn. SAGE, London.

Silva, F., Heikkila, T., Filho, F. and Silva, D. (2013) Developing sustainable and replicable water supply systems in rural communities in Brazil. *International Journal of Water Resources Development*, **29**(4), 622–635.

Wasserman, S. and Fraust, K. (1994) *Social Network Analysis: Methods and Application – Structural Analysis in the Social Sciences (Book 8)*, 1st edn, Cambridge University Press, New York.

Whittington, D. (1990) Estimating the willingness to pay for water services in developing countries: a case study of the use of contingent valuation surveys in southern Haiti. *Economic Development and Cultural Change*, **38**(2), 293–311.

Whittington, D., Davis, J., Prokopy, L., Komives, K., Thorston, R., Lukacs, H., Bakalian, A. and Wakeman, W. (2009) How well is the demand-driven, community management model for rural water systems doing? Evidence from Bolivia, Peru and Ghana. *Water Policy*, **11**, 696–718.

WHO/UNICEF Joint Monitoring Program (JMP). (2015) *Improved and Unimproved Water Sources and Sanitation Facilities*. Available at http://www.wssinfo.org/definitions-methods/watsan-categories/ (accessed 27 May 2016)

Yin, R. (2002) *Case Study Research: Design and Methods (Applied Social Research Methods)*, 3rd edn. SAGE Publications, Inc., Los Angeles.