


Research Paper

Impact of regional water supply, sanitation et hygiene (WASH) program in Senegal on rural livelihoods and sustainable development

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ABSTRACT

In 2006, Senegal benefited from the African Development Bank's (AfDB) Rural Water Supply and Sanitation Initiative (RWSSI) a WASH sub-program for 17,100 households in rural areas in the regions of Louga, Ziguinchor and Kolda. A project results assessment was conducted in 2016 by the AfDB Independent Development Evaluation (IDEV) to measure the sub-program impacts on the living conditions of the communities. This approach allowed the measurement of project impacts based on comparative pre-and post-intervention data, as well as beneficiaries and non-beneficiaries' groups considering collected quantitative data (963 households, 38 schools, 23 health centres and 46 GPS points of infrastructures) and qualitative data (31 individual interviews and 4 focus group discussions). Several analyses (descriptive statistics, correlative analysis, effects and impact analysis with Average Treatment Effect (ATE) and cartographic treatment) were carried out to determine the project's results indicators as well as their overall effects. The results show an access rate of 73% for drinking water among beneficiaries against 6% among non-beneficiaries, and an access rate of 72% for sanitation (improved latrine) in the treatment areas against 33.7% in the control areas. In sub-program focus areas, an increase in the quantity of water used per household by 157 liters, a reduction in water price by 0.072 USD and reduction in time taken to supply drinking water of 65 minutes were observed. Also, it was noted a reduction in arduousness of carrying water by 2 km from the supply point, an increase in the schooling rate of children, especially girls, in income-generating activities, a decrease in the number of sick people avoided by 2 persons and increase in medical treatment avoided were noted. The progress made by the project's achievements demonstrate that improvement in water access, sanitation and hygiene access is one of the main drivers and levers of change and transformation of the households' living conditions in rural areas, often explaining the priority given to this area of intervention within the implementation of the MDGs and SDGs.

Key words: hygiene, impact, sanitation, Senegal, sustainable development, WASH sub-program, water

HIGHLIGHTS

- Increase of water and sanitation level access in rural areas.
- Links between WASH and improved living conditions of communities.
- Water and sanitation are major issues for communities' sustainable development.
- Water and sanitation are main determinants for reducing poverty incidence, improving well-being and health and community development.

INTRODUCTION

Several studies have demonstrated the impact of access to drinking water and sanitation on the improvement of living conditions, health, and well-being of populations (Fewtrell *et al.* 2005; Bartram & Cairncross 2010; UNICEF-WHO 2019; UN Water-WHO 2019). Consequently, the United Nations decided within the Millennium Development Goals (MDGs) to

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reduce by half the proportion of the population without sustainable access to adequate drinking water supply and sanitation services before 2015 (Cairncross *et al.* 2010; UNICEF-WHO 2015). This engagement was reiterated with the Sustainable Development Goals (SDGs) adopted by all UN Member States in 2015, in particular, concerning Goal 6 that aims to ensure access to water and sanitation for all by 2030.

In this context, the African Development Bank (AfDB) launched the Rural Water Supply and Sanitation Initiative (RWSSI) in 2004 through the African Development Fund (ADF) to contribute to the achievement of the MDGs for drinking water supply and sanitation in Africa rural areas (AfDB 2015) and the subsequent Sustainable Development Goals 6.1 and 6.2.

The Government of Senegal benefited from the sub-program implemented between 2006 and 2010, with the expectation to ensure a rate of access to drinking water and sanitation of 82 and 63% respectively by 2015 (compared to 64 and 26%, respectively in 2005) through potable water and sanitation infrastructure. The sectorial objective of the sub-program was to contribute to the socio-economic, environmental, and health conditions improvements of rural populations in Louga, Ziguinchor, and Kolda regions by ensuring direct access to drinking water for 183,000 people, latrines for 172,000 individuals (about 17,100 households), and collective toilets for the entire population (Figure 1). The overall sub-program's estimated cost was US\$ 29 million and was jointly funded by the ADF (US\$ 25 million loan), the Government of Senegal (US\$ 3.118 million), and the beneficiary populations (US\$ 0.882 million). The mobilized funds made it possible to build hydraulic infrastructure and latrines that facilitated access to drinking water and sanitation services in rural target areas (AfDB 2016a; ANSD 2019). Through the African Water Facility initiative of the African Development Bank, the Government of Senegal has given greater priority to regional well-targeted and sustained WASH investments that can simultaneously reduce inequalities in access to drinking water and sanitation and rural poverty.

Apart from its coordination and management, the sub-program consisted of two main components: (i) development of basic drinking water supply and sanitation infrastructure; and (ii) institutional support to structures under the sub-programs.

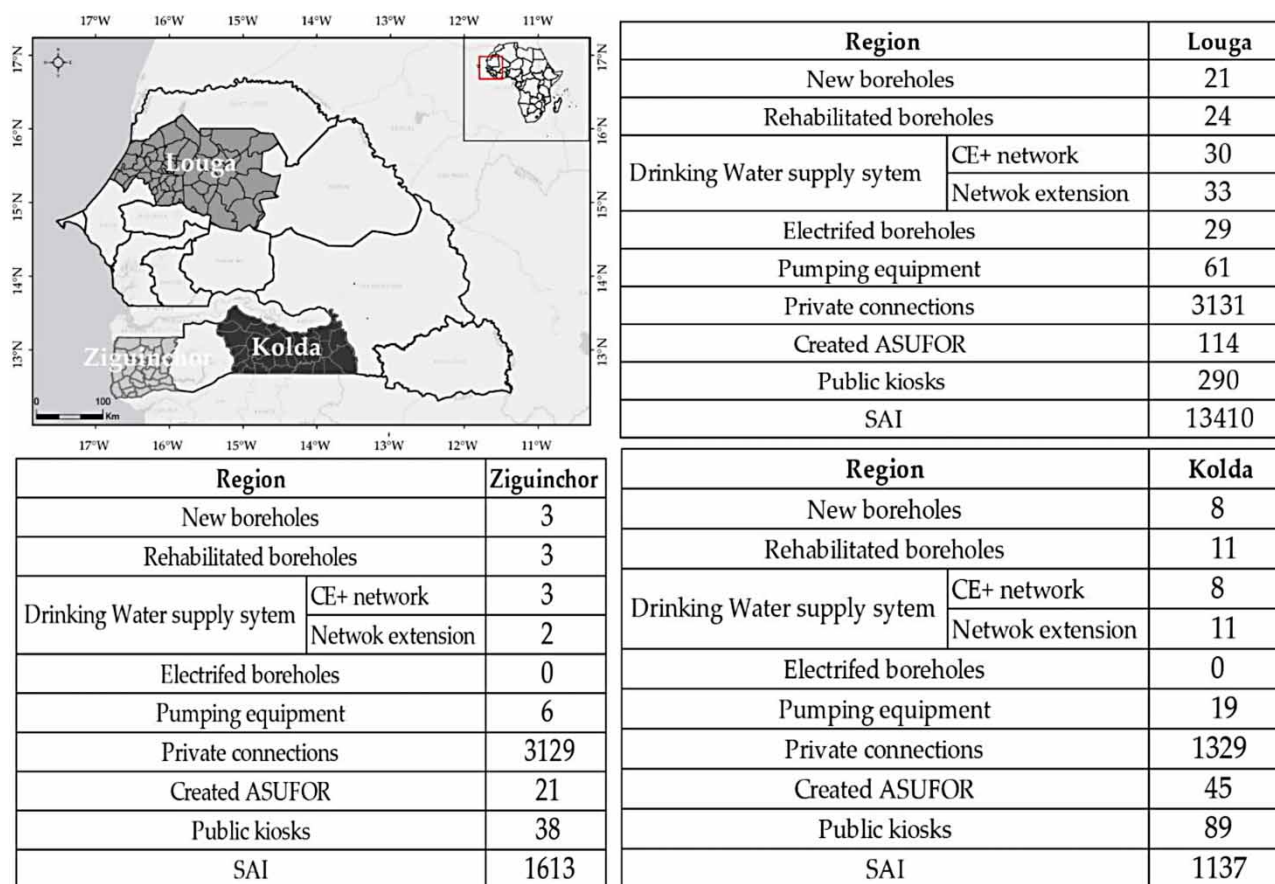


Figure 1 | Spatial distribution of water, sanitation and hygiene services of sub-program interentions in Louga, Kolda and Ziguinchor.

The expected outputs of the sub-program are: (i) 17,100 new household latrines and wash tubs fitted with hand-wash basins; (ii) 477 new multi-compartmental latrines, constructed at village public facilities (markets, schools, health centres and other public places); (iii) 151 masons and 169 trained school teachers; (iv) 400 female intermediaries put in place for the purposes of hygiene at village level; (v) 27 new boreholes constructed and 52 old ones rehabilitated; (vi) 85 new drinking water supply and sanitation (DWSS) systems constructed, including a water tower to serve an estimated 240 villages; (vii) 86 pumping units (motors and pumps) provided and installed; (viii) 30 borehole electrifications undertaken; (ix) 9,050 individual connections put in place; (x) 750 distribution meters and 178 production meters installed; (xi) 178 borehole users' associations (ASUFOR) put in place, supervised and trained in the management and maintenance of water points; (xii) 178 ASUFOR managers and borehole operators trained; and (xiii) training, outreach, and awareness raising campaigns undertaken in nearly 240 villages in the three regions (Louga, Ziguinchor and Kolda) of the sub-program. The choice of the sub-program intervention areas is justified, *inter alia*, by the following three factors: (i) state of access to drinking water and sanitation services, (ii) the inter-sectoral synergy potential in the Louga region, with the rural electrification financed also by the ADF, (iii) the top priority given by the government to the Casamance reconstruction program.

An independent evaluation of the results of the WASH sub-program was conducted in 2016 (AfDB 2016a). This paper draws on the achieved evaluation by enhancing the analytical methodology of socio-economic, environmental and health impacts of the interventions on beneficiary communities. The present paper confirms existing scientific evidence on the impact of access to drinking water and sanitation in poverty reduction, improvement of living conditions, hygiene, and health (Hunter *et al.* 2010; AfDB 2016b; Mills & Cumming 2016; Null *et al.* 2018).

MATERIALS AND METHODS

The initial independent evaluation used a theory-based approach. For this paper, the methodology was strengthened by including a quasi-experimental impact evaluation method to assess the 'net effect' of the intervention in particular outcomes. A geocoding approach was also used to visualize the main output and impact indicators of the sub-program at the level of rural communes. Without having a baseline study completed before the start of the project, the approach is based on a model of comparative mixed estimates before and after intervention in the target areas (beneficiary communities) and control areas (non-beneficiary communities or control cases) for the measurement of the direct and indirect effects of the WASH sub-program (Hartinger *et al.* 2016). The evaluation process was based on various methods, including the analysis of relevant documents related to the WASH sub-program, quantitative and qualitative field surveys targeting beneficiary and non-beneficiary communities, and the processing and analysis of data collected using statistical methods (effects analysis, correlation, and principal component analysis) to determine the indicators of the project's expected results and effects (Cerulli 2014; Huber 2015).

Document analysis

A series of meetings were held with the heads of the Program Coordination and Monitoring Planning Unit (CPCSP), the Directorate of Rural Hydraulics (DHR), the Directorate of Water Resources Management and Planning (DGPPE), the Sanitation Directorate (DA), and the Office of Rural Water Drilling (OFOR). Also, the 2013 Senegalese population data and a cartographic base of localities in Senegal at the commune level were respectively collected from the National Statistics and Demography Agency (ANSD) and the Ecological Monitoring Centre (CSE). This first stage of document analysis helped to ascertain preliminary information and the list of beneficiary localities (60 rural communes¹ and 240 villages²) provided by CPCSP as well as the ANSD database, which was considered as a sampling base to select villages not benefiting from the project.

¹ Rural communities (Communautés rurales) (CR) are the fourth-level administrative divisions in Senegal. They are administrative subdivisions comprising the villages, but are distinct from the urban communes and municipalities concerning medium or large towns. 5 Sources: https://en.wikipedia.org/wiki/Rural_communities_of_Senegal.

² The Villages of Senegal are the lowest level administrative division of Senegal. They are constituted 'by the grouping of several families or carrés in a single agglomeration.'

Field data collection

Households, schools, health facilities and infrastructures surveys

Sampling was based on a list of beneficiary localities in Louga, Kolda, and Ziguinchor with the support of the AfDB evaluation team. This list allowed the survey to be stratified according to the type of infrastructures to make a reasonable and representative sample of villages in each of the strata concerned according to their importance: multi-village water storage (water point that supplies many localities within a radius of 7–10 km maximum), village water drilling, water supply by network extension, special connections, and latrines. The choice of localities to be included in the sampling was determined based on the type, diversity, and size of interventions focused on improving access to drinking water and sanitation services. Non-beneficiary villages were selected based on the list of localities in Senegal located in the same program intervention area provided by ANSD. This concerns localities which have not benefited from any water or sanitation programs provided by the government or aid agencies. In close collaboration with the AfDB evaluation team, it was recommended to target a sample of 59 villages for the survey, including 46 beneficiaries and 13 non-beneficiaries in a set of 23 selected rural communes (grouping of several villages around a central locality), and to question at least 15 households per locality. Thus, the household surveys covered a sample of 963 households in total, including 762 beneficiary and 201 non-beneficiary households. The surveys also covered 38 schools (36 in beneficiary and 2 in non-beneficiary localities) and 23 health facilities (21 in beneficiary and 2 in non-beneficiary localities) in the villages and communes. Using Global Positioning System (GPS) geospatial location, various information (quality, functioning, utilization) on the hydraulic and sanitation infrastructures in 46 beneficiary villages in the intervention areas was also collected. The quantitative data collection was conducted from January 2 to 22, 2016 using tablets equipped with Open Data Kit (ODK) software integrating a quality control system. Data recalling (memory recall) was used because no adequate baseline was collected for the households surveyed in the different sampled communities. The use of such a tool typically generates data collection bias because it is difficult to remember. Accordingly, the diff-in-diff method could not be appropriately applied.

Key informant surveys

The aim of the key informants surveys was to collect meaningful information to help better understand trends in the quantitative data. This included two main components: (i) face-to-face interviews with key actors of the WASH project (3 heads of regional hydraulic division, 6 heads of regional sanitation division (3 predecessors and 3 successors), 6 heads of Drilling Users Associations (ASUFOR), 5 representatives of local management committees, 6 local elected officials and 1 administrative representative and; ii) 6 focus group discussions were held with women from the beneficiary villages with respectively 4 in Louga, 1 in Kolda and 1 in Ziguinchor led by a senior scientist with a sociology background.

Data analysis

Quantitative data analysis was carried out using SPSS for descriptive statistics, STATA for assessing project impacts, and XLStat to determine indicators for measuring results achieved and the direct, intermediate, and long-term effects of the WASH sub-program as per the intervention's theory of change, but also the correlation between interconnected variables.

The indicators for measuring the project's impact are based on techniques for matching the variables that are supposed to explain the effects of the intervention using the method of weights such as Inverse-Probability-Weight. IPW allows the weight to be used as a means of correcting the imbalance in observed characteristics between beneficiaries and non-beneficiaries (Cerulli 2014; Huber 2015). Otherwise, it is about finding a non-beneficiary with fairly similar characteristics for each project beneficiary who will act as a counterfactual. Balance tests were carried out to ensure comparability between treatment and control groups. Then, the Average Treatment Effect (ATE) method defined by $ATE = E(Y_1 - Y_0)$ was used. It represents the expectation of the difference between what the individual's situation would be with intervention (Y_1) and what it would be without intervention (Y_0). In addition to these statistical analyses, correlation and association tests (Pearson Chi-2, correlation matrix, and PCA) were also used.

Concerning the impact assessment on socio-economic conditions, an analysis of the benefits and advantages of the project was carried out using an approach that consists of calculating the percentage of households engaged in income-generating activities related to the WASH sub-program, the annual income generated by these activities, and the number of individuals per household engaged in an income-generating activity related to the project. The impacts on environmental and health conditions were analyzed using a method integrating the global costs of treatment of a water-related disease

estimated at 52.05³ USD per household per year (AfDB 2016a), the rate of water-related diseases reduction according to household surveys, and the number of sick persons avoided per year between the beneficiary and non-beneficiary households. The impacts on the health system were analyzed by integrating the global treatment costs of a disease in health facilities estimated at 36.5 USD per person and per year (AfDB 2016a), the rate of beneficiaries concerned by a reduction of waterborne diseases and the number of sick persons avoided per year between the beneficiary and non-beneficiary households.

ArcGIS Software version 10.2.1 for map production was used to visualize the main outputs and impact indicators of the sub-program at rural community level and also of drinking water and sanitation facilities built using functionality and cleanliness criteria.

RESULTS AND DISCUSSIONS

Water supply and sanitation achievements of AfDB sub-program

The WASH sub-program achieved most of its expected outputs with physical implementation rates often exceeding the projected results in several intervention areas. In the field of hydraulics, the outputs are composed of multi-village water towers, boreholes, water supply systems by network extension, private connections, and pumping equipment, of which 69% occurred in the region of Louga, 24% in the region of Kolda and 7% in the region of Ziguinchor (Figure 1). For the sanitation component, improved latrines and hand-washing facilities were built, as well as new multi-cabin toilets for village public infrastructure (markets, schools, health centers, places of worship, and other public places).

The distribution of sanitation facilities by region shows that the villages of Louga received 83% of the installed latrines, while the localities of Kolda and Ziguinchor obtained 7 and 10%, respectively. Indeed, Louga was considered a priority region for access to improved latrines. To support the strengthening and development of community and institutional capacities in water and sanitation sector, ASUFOR, local committees for public services management, awareness relays for Information, Education and Communication (IEC) and Local Hydraulic and Sanitation Plans (PLHA) were implemented (Figure 1).

Impacts of water supply and sanitation interventions in rural areas

The direct and indirect effects of WASH sub-program achievements in rural areas are seen in the improvement of access to drinking water and sanitation as well as the transformation of socio-economic, environmental, and health conditions in beneficiary communities. In the communities benefiting from the WASH sub-program in Louga, Kolda, and Ziguinchor, the achievements have led to a considerable improvement in the conditions of drinking water and sanitation access. Moreover, the differences in the direct, intermediate, and long-term effects are notable between the beneficiary and non-beneficiary households.

Improvement of access to drinking water, sanitation and hygiene

In total, 73% of households visited in beneficiary localities have an improved water supply source compared to 6% in non-beneficiary villages. In beneficiary villages, 88% of households have access to drinking water as a result of the achievements of the WASH sub-program between 2006 and 2010 (Figure 1(b)–1(d)). Around 74% of health facilities and 79% of schools visited have a drinking water supply, 40 and 47% of which are attributed to the WASH project. With regard to sanitation access, 72% of households in beneficiary villages have improved latrines compared to 34% of households in non-beneficiary localities (Figure 2).

The WASH sub-program provided access to latrines for 43% of households in beneficiary localities. Similarly, 87% of the health facilities and 84% of the schools visited have improved latrines, of which 40 and 63% respectively were built under the WASH Initiative. These results show that WASH sub-program interventions contribute to the achievements of the MDGs and SDGs in target areas, which were projected to achieve access rates of 82% to drinking water and 59% to sanitation by 2015 (MHA 2016). Moreover, the access rates recorded in some beneficiary localities, especially in the Louga region, are well above the national average (67% for drinking water and 34% for sanitation) and range between 85 and 90% for drinking water and 66 and 70% for sanitation (Figures 3–5).

³ Corresponding to 31,633 XOF as January 2016.

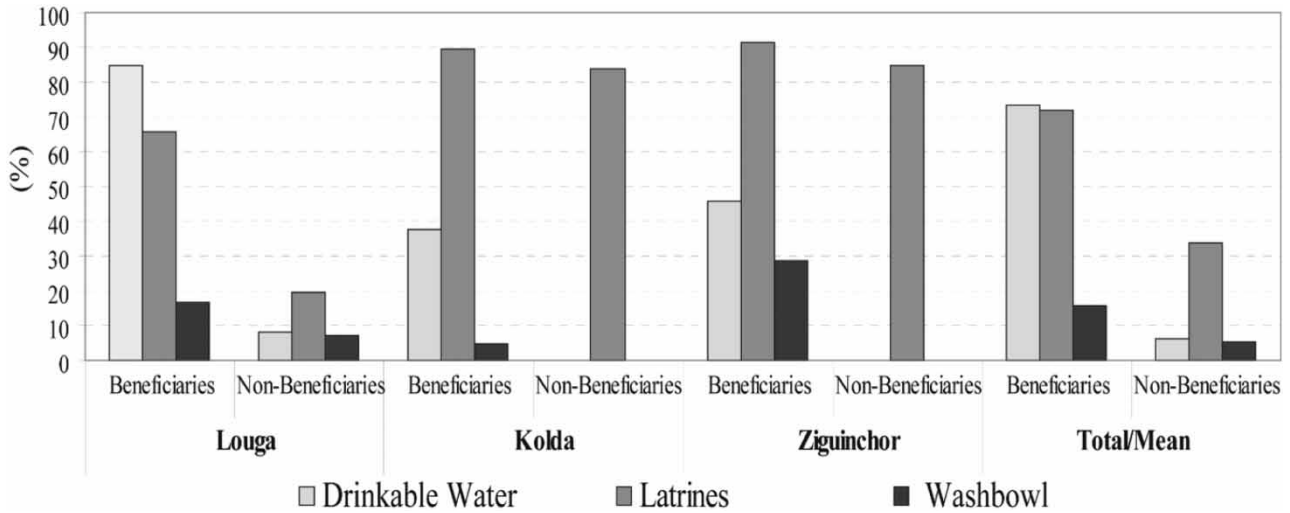


Figure 2 | Measurement of the level of household access to drinking water and sanitation.

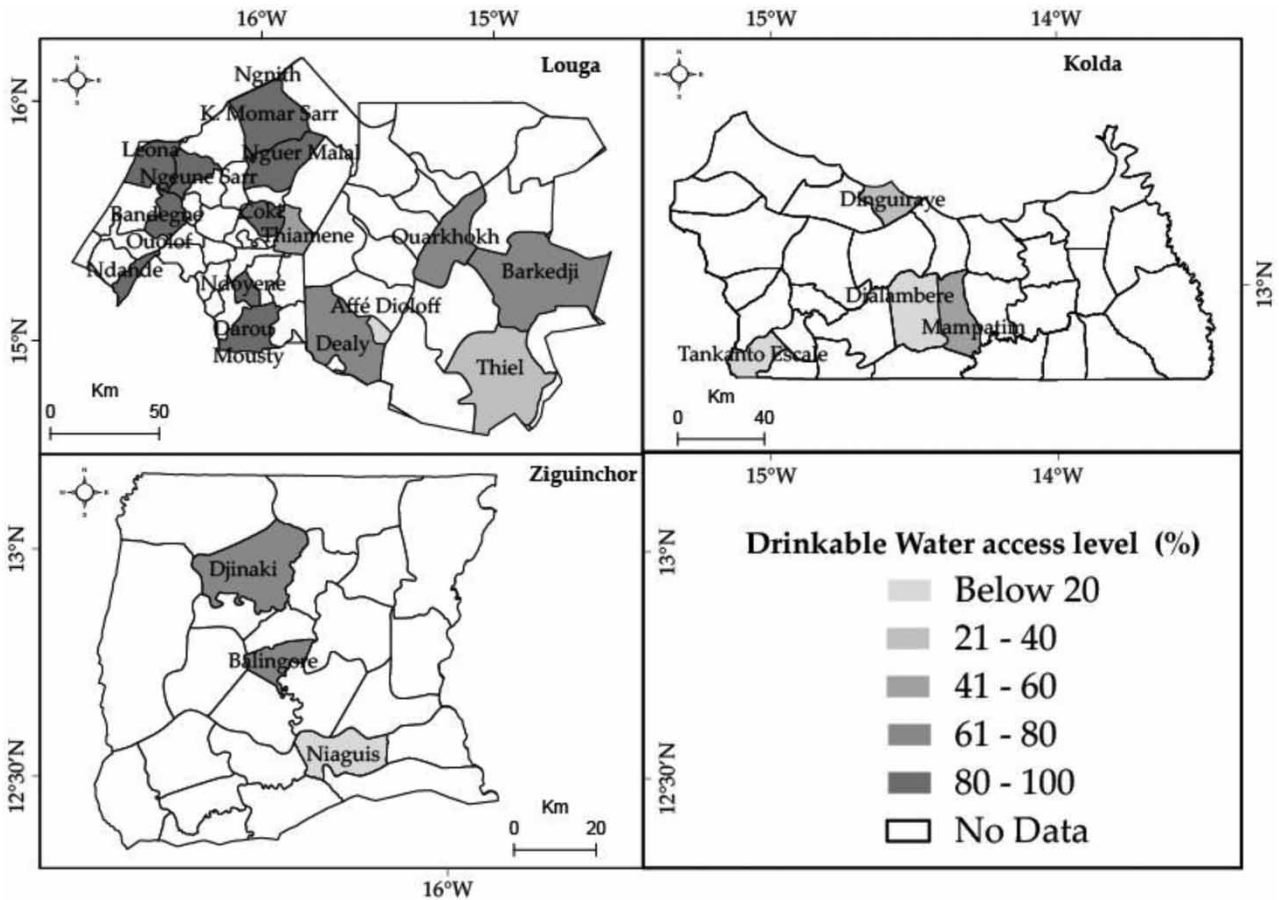


Figure 3 | Spatial distribution of drinking water access within sub-program interventions in Louga, Kolda and Ziguinchor.

The study results show that the MDGs and SDGs have almost been achieved and sometimes even exceeded in the project intervention areas with indicators of access to drinking water and sanitation above national rates and targets. Even with indicators covering years after the ADB Sub-Program (2012–2018), access rates to drinking water and sanitation in the intervention areas are still much higher than those met at the national level (ANSD 2019). This highlights the importance of the progress made under the Rural Drinking Water and Sanitation Sub-Program. By reducing inequalities in access to

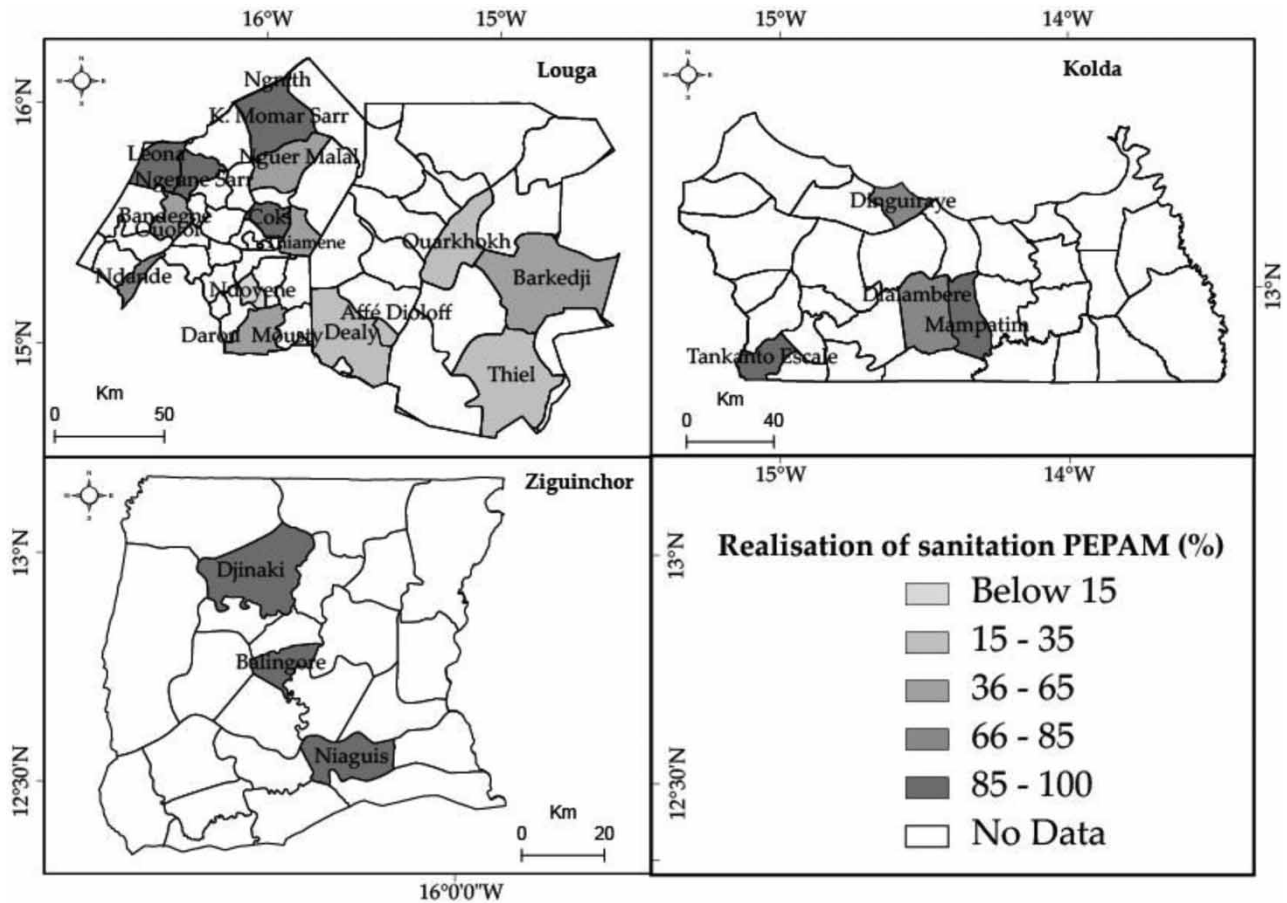


Figure 4 | Spatial distribution of latrines access within sub-program interventions in Louga, Kolda and Ziguinchor.

drinking water, sanitation and hygiene and the development gap in the target regions of WASH investments, the results show that progress made increased national statistics on water and sanitation.

The Joint Monitoring Program report (UNICEF-WHO 2015, 2019) shows that Senegal has made significant progress in access to drinking water (41% in 1990 to 67% in 2015) and sanitation (21% in 1990–34% in 2015) in national rural areas. However, the indicators provided in the latest national review of PEPAM in 2014 show a rate of 84% for drinking water and 39% for sanitation in Senegal's rural areas (MHA 2016; ANSD 2019). This means that, with results exceeding the targets, the interventions in the sub-program area have made a significant contribution to the achievement of the MDGs and SDGs in drinking water and sanitation in Senegal (AfDB 2016a; AfDB 2016b). Therefore, as local actors and key persons interviewed in the target field, the construction of water and sanitation infrastructures in rural areas is the first factor that facilitated or improved access to these types of basic social services. These observations have also been demonstrated through numerous studies on the role of investments in the rural water and sanitation sector (Piper *et al.* 2017; USAID 2017; World Bank 2018; McMichael 2018; USAID 2019).

The impact assessment method using IPW reveals a significant association at the 1% threshold between the project's achievements and the main indicators for measuring progress in access to water: increase in the quantity of water used per household by 156.87 liters (P -value=0.0001), reduction in the price of water by 0.072 USD of the average cost (P -value=0.026), reduction of 64.7 minutes of drinking water supply time (P -value=0.0001), reduction in the arduousness of carrying water by 2.32 km from the distance traveled to the supply point (P -value=0.0001) (Table 1).

Impact of water and sanitation services on the socio-economic conditions of households

Overall, statistical analyses show that 47% of beneficiary households see an improvement in the schooling of children, especially young girls, compared to 10% of households in non-beneficiary localities (Figure 6). Children's schooling was

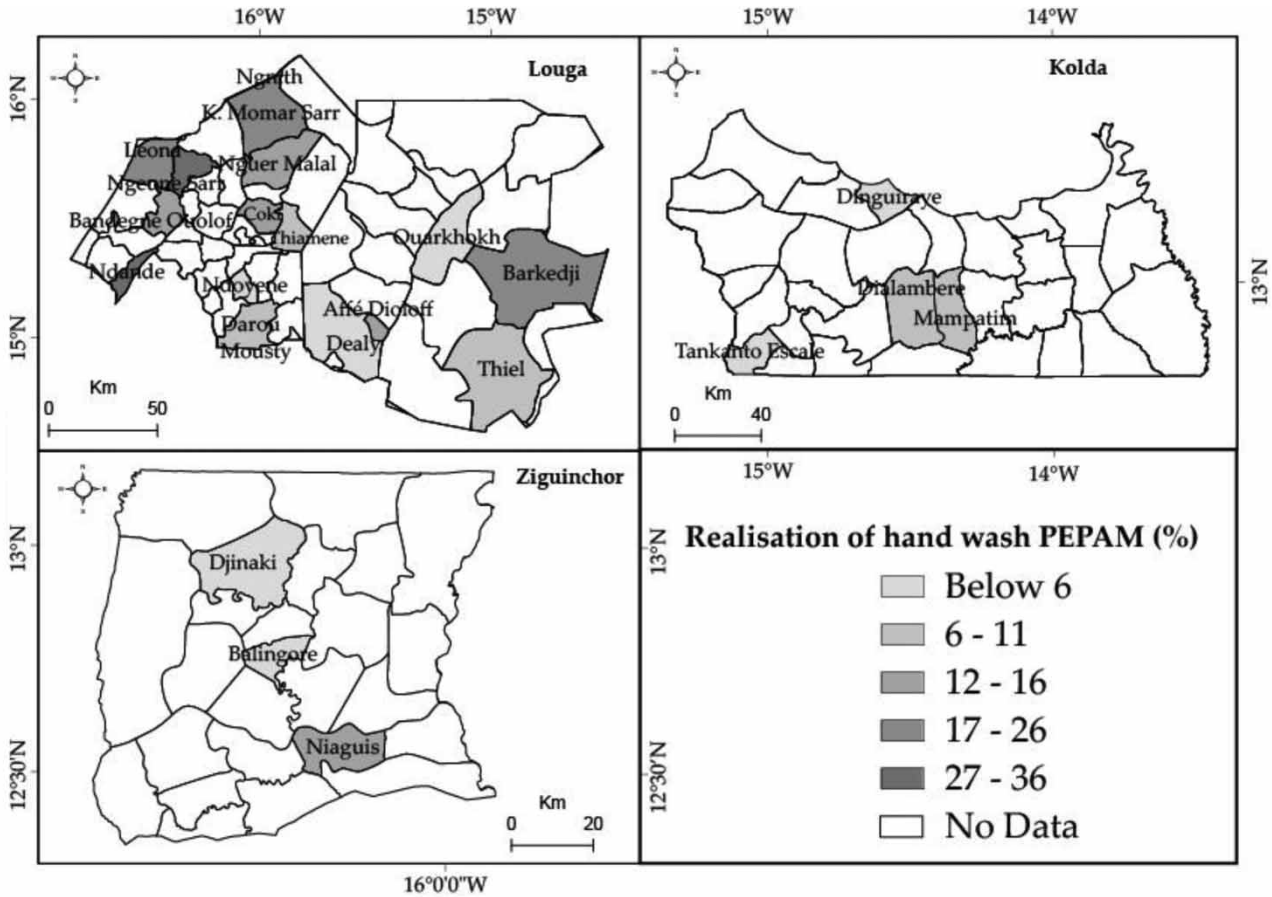


Figure 5 | Spatial distribution of hand washing within sub-program interventions in Louga, Kolda and Ziguinchor.

Table 1 | Measurement of the effects of access to drinking water and sanitation after 2006

Household type Period	Beneficiary households		Non-beneficiary households	
	Before 2006	After 2006	Before 2006	After 2006
Quantity of water (in liters) available and used per household	267,6	411,9	327,3	360,4
Time passed (in minutes) to have access to water supply	54,2	10,4	143,1	136,8
Distance traveled to access the water supply point	1,2	0,3	4,1	4,1
Water average cost in local currency (USD)	0.161	0.481	0.56	0.505
Number of children schooled per household after 2006	1,6	4,0	0,6	2,5
Average number of monthly absentees per village in visited schools	10	3	8	6
Number of patients avoided with access to water and sanitation per household	25,4	12,7	15,0	7,2
Number of treated patients avoided with access to water and sanitation	22,4	5,1	13,3	2,8
Average number of monthly consultations per village for waterborne diseases in health facilities visited	15	7	13	9

measured through information from households and schools where the average number of absences per student was assessed before and after the project. The impact of the project is positive but the difference is not significant (P -value=0.30) compared to non-beneficiary villages. The analysis only shows an increase of one more child in school per year. Then, 79% of the heads

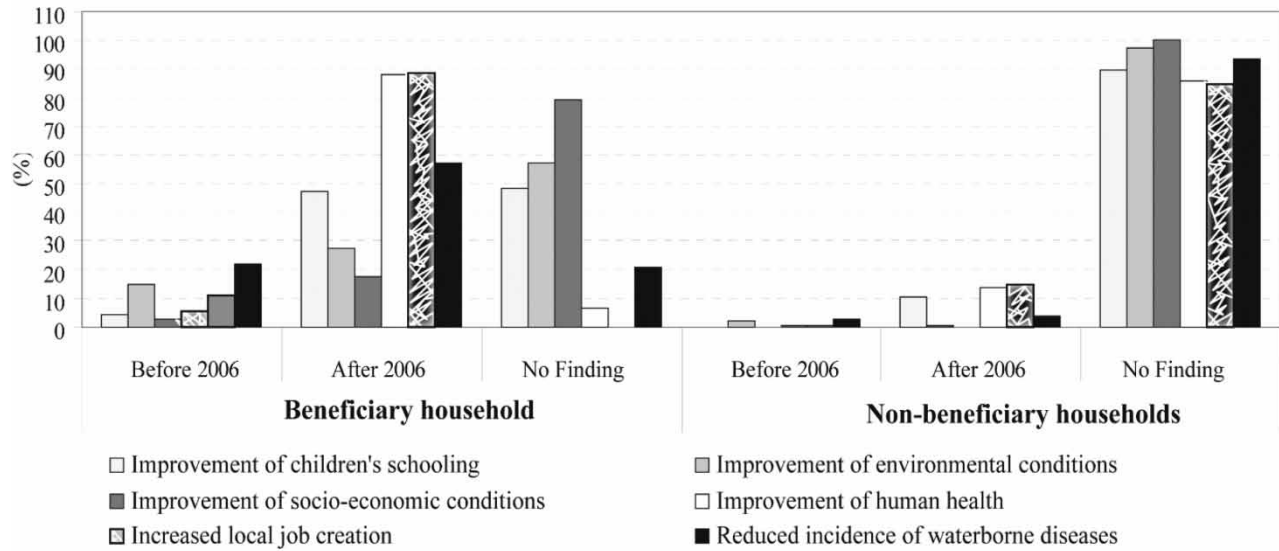


Figure 6 | Accountability of the effects of access to drinking water and sanitation on the improvement of household living conditions.

of visited schools observed more regular attendance of children, with the number of monthly absentees varying from 10 before 2006 to 3 after 2006. However, it has been difficult to determine the real impact of the project on girls' schooling due to a smoothing effect linked to the government mass education approach, which affected both beneficiaries of achievements and non-beneficiary localities.

Concerning the socio-economic effects, 18% of households in the beneficiary localities were able to develop an income-generating activity (agriculture, market gardening, livestock, poultry farming, trade, etc.) employing at least 2 persons per household with an additional average annual individual gain of 245.6 USD due to water investments. The econometric analysis of the contribution of these income-generating activities forecasts benefits of 17 million USD by the project horizon of 2021 (AfDB 2016a). Likewise, 5% of households in the beneficiary localities see the creation of at least one salaried job (work managers, borehole operators, water supply operators, surveyors, laborers, drainers, etc.), generating an additional average annual income of 254.5 USD, which represents 2.5 million USD economic benefits by 2021.

The project's impact on the improvement of household living conditions is well perceived by the beneficiaries, 28% of whom believe that their socio-economic status has changed, compared to 0.5% for non-beneficiaries. Moreover, 18% claim an increase in local job creation after 2006. The cumulative effect of the gains related to job creation and the development of income-generating activities has had an impact on reducing poverty incidence in intervention areas where more than 70% of households have a monthly income greater than 220,9 USD, thus exceeding the national monetary poverty line in rural areas set at 210.5 USD. The average monthly income was 202,4 USD in non-beneficiary households.

The reduction of water-borne diseases is reflected in gains in health expenditure for households and health system. The health gains are calculated using the estimation cost for waterborne disease in project funding appraisal reports (AfDB 2016a). Based on the overall treatment costs (transport, drugs, hospitalization, opportunity cost of work, food, etc.) of water-related disease of 62.2 USD per person/year for households, the econometric analysis results show a substantial gain in health expenditure of 14.4 million USD. Similarly, based on the treatment cost of these types of disease (44 USD by a health centre), a gain of 10.1 million USD is expected for the health system.

The economic internal rate of return (EIRR) associated with the project is 16% above the opportunity cost of capital of 12%. This is lower than what the Government of Senegal had projected (27%) in their launch report. One of the reasons for this decrease is that the percentage of people who benefited from an increase in income due to the project is not very high (18%), the majority being in a stagnant income situation.

The contribution to the achievement of intermediate and long-term socio-economic and health effects can be seen in the light of jobs created, increase in local income and investment capital of the beneficiaries, reduction in health expenditure, and improvement in health status of the population (Clasen & Laurence 2008; WSP- World Bank 2012; Darvesh *et al.* 2017). The results of the evaluation show that more than three-quarters of households have an average income above the national

poverty rate of 2014 in rural areas. Therefore, these positive local externalities of investments in drinking water and sanitation have helped to achieve the goal of reducing the poverty incidence from 60% in 2005 to 30% in 2015 (AfDB 2016a; Tamboura *et al.* 2019). Field observations as well as interviews with beneficiaries showed that the WASH initiative has many positive externalities, materialized by its capacity to structurally transform social and economic life, which appears to be a solid foundation for the community development process.

Impact of water supply, sanitation, and hygiene interventions on environmental and social conditions

The increase in water availability in households, schools, and health centres, combined with awareness-raising activities in the form of IEC in households, schools, and health centres, has led to a significant improvement in hand-washing practice, which tends to be regular and systematic before eating and after using the toilets.

The statistical analysis revealed that 88% of households in the beneficiary localities note an improvement in environmental hygiene (reduction of open defecation, better management of polluted wastewater, and reduction of the water and soil contamination risks) against 14% for non-beneficiary households after 2006. Only 21% of village households in target areas continue to practice open-air defecation compared to 56% of households in non-beneficiary localities. The environmental impacts of the sub-program are well perceived by the beneficiary households, of which 92% note a reduction in OAD, 61% observe better wastewater management, and 59% note a reduction in water and soil contamination risks.

The key informant interviews confirm the reality of these project impacts on environmental conditions in the majority of beneficiary localities, especially since the end of the WASH sub-program. The large-scale achievements in the field of drinking water and sanitation have led to economic and social progress in the rural area, while the community management model for drinking water services based on the establishment of ASUFOR has a structuring socio-economic function with investment in basic social services such as electricity, education, health, etc, that has made it possible to initiate a process of sustainable community development.

Impact of water supply, sanitation, and hygiene interventions on health conditions improvements

The indirect effects of the project on health can be captured through the perception of improved human and animal health, the observation of reduced incidence of waterborne diseases, and the gain in health expenditure for both households and the health system (Table 2).

In total, 89% of beneficiary households observed an improvement in human and animal health against 15% of non-beneficiary, and 57% of respondents in the intervention zones observed a reduction in the frequency of water, sanitation, hygiene, and nutrition-related diseases (individual and collective hygiene, reduction in water-borne diseases, reduction in malnutrition, reduction in health expenditure, etc.) against 4% in the control areas after 2006. The analysis shows a gain of 2 sick people avoided on average per year in beneficiary households (P -value=0.0001) when compared to non-beneficiary households. Similarly, a gain of one medical treatment avoided due to waterborne diseases was noted per household/year after 2006 (P -value=0.001). The average number of people affected by pathologies related to water and sanitation dropped from 14 before 2006 to 6 after 2006, while the proportion of patients treated for this type of syndrome decreased significantly from 12 before 2006 to 2 after 2006. These observations are corroborated by 74% of health workers who note a significant

Table 2 | Analysis of the effects of access to water and sanitation between beneficiaries and non-beneficiaries after 2006

Beneficiaries vs non-beneficiaries	ATE (Average Treatment Effect)	Robust std Error	Z Statistic	P-value
Quantity of water available and used per household	105.1 (**)	43.12	2.44	0.015
Reduction of the cost (XOF) per cubic meter of water	45.42 (**)	22.16	2.05	0.04
Time traveled (in minutes) to water supply point	-67.3 (***)	6.39	-10.52	0.000
Distance traveled to access the water supply point	-2.69 (***)	0.28	-9.42	0.000
Number of children schooled per household after 2006	1.55 (***)	0.56	2.73	0.006
Number of patients avoided with improved access to water and sanitation	-1.69 (***)	0.41	-4.06	0.000
Number of treated patients avoided per household after 2006.	-0.76 (***)	0.21	-3.58	0.000

drop in the frequency of water-related diseases in the same proportions described by households. Health professionals noted a reduction in the number of patients for this type of pathology, going from an average of 15 contacts before 2006 to 7 consultations per month after 2006. As showed in the table, significant effects are in bold (** for p -value <1%; * for p -value <5%; * for p -value <10%).

The reduction by more than half of the number of people affected by waterborne diseases has contributed significantly to the reduction in the prevalence of diseases related to drinking water and sanitation, which was targeted to be reduced from 22% in 2005 to 18% in 2010 in Louga, Kolda, and Ziguinchor. These interventions have certainly made an impact on child mortality rate decrease, which has declined from 78‰ in 2005 to 60‰ in 2013 (ANSD 2019). In many development contexts, improvements in water supply and sanitation systems have been shown to reduce child mortality by more than 30% and overall morbidity by almost 37%, particularly in combination with handwashing. WASH interventions, including hygiene education and simple handwashing, can reduce diarrheal diseases by up to 45% (Joshi & Amadi 2013; Wolf *et al.* 2014; UNICEF-WHO 2015; WHO-UNICEF 2015; Ramesh *et al.* 2015; Taylor *et al.* 2015)

Table 3 and Figure 7 show the correlation matrix of the different effects of WASH Sub-program achievements, considering several investigated variables (monthly household income, quantity of water available, time to water supply, water duration storage, water cost, distance to water supply, number of children schooled, number of patients avoided, number of treated patients avoided).

The intermediate correlation matrix illustrates considerable similarity or proximity between five effects related to socio-economic, environment, education, and health conditions improvements, as shown by the segments F1 and F2 with a significant cumulative variance (89%).

Table 3 | Correlation matrix between the different effects of access to drinking water and sanitation

Variables	Monthly household income	Quantity of water in liters	Time to water supply in minutes	Water duration storage/days	Water cost XOF/cubic meter	Distance to water supply/Km	Number of children schooled	Number of patients avoided	Number of treated patients avoided
Monthly Household Income	1.0000								
Quantity of Water in Liters	0.2286 0.0000	1.0000							
Time to Water Supply in Minutes	-0.0210 0.5147	0.1833 0.0000	1.0000						
Water Duration Storage/Days	-0.0338 0.2968	-0.0467 0.1527	0.0474 0.1433	1.0000					
Water Cost XOF/Cubic Meter	-0.0053 0.8706	0.1326 0.0000	0.2946 0.0000	0.0290 0.3702	1.0000				
Distance to Water Supply /Km	-0.0880 0.0063	0.1057 0.0012	0.7199 0.0000	0.0227 0.4831	0.2812 0.0000	1.0000			
Number of Children Schooled	0.1811 0.0039	0.0269 0.6719	-0.1623 0.0099	-0.1205 0.0560	-0.1129 0.0736	-0.1447 0.0215	1.0000		
Number of patients avoided	0.0615 0.2376	-0.1057 0.0441	-0.0137 0.7921	-0.0925 0.0763	-0.2173 0.0000	0.0585 0.2624	0.4296 0.0000	1.0000	
Number of treated patients avoided	0.0078 0.9000	-0.0493 0.4333	-0.0166 0.7894	-0.0095 0.8799	-0.1917 0.0019	0.0636 0.3079	0.3312 0.0045	0.8308 0.0000	1.0000

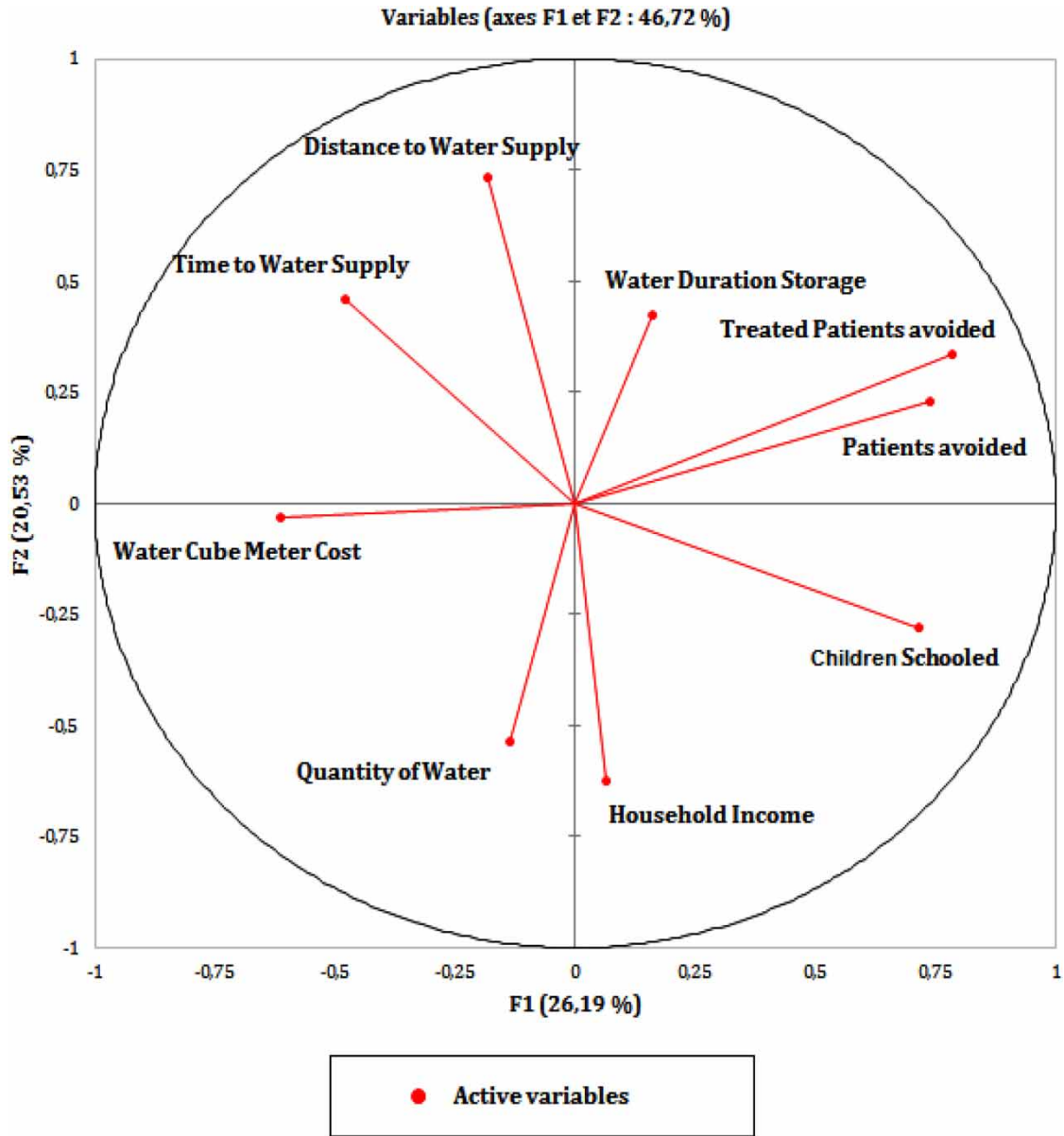


Figure 7 | Analysis of correlations between variables and factors: effects of access to water and sanitation.

With interventions in drinking water, vector projections show an interconnection between variables such as increase of available water amount, time and distance reduction to water point and water cost decrease. This close relationship between these different variables leads to a chain of impacts linked to the improvement of access to drinking water and sanitation such as the reduction of water storage duration, increase of children’s schooling rate and level of household income, reduction in the number of sick and treated people.

Effects sustainability of water supply, sanitation, and hygiene interventions

During the field data collection campaign, the GPS points of 99 completed hydraulic infrastructures, including 10 multi-village water towers, 25 boreholes, 57 standpipes, and 7 public latrines, were collected for geo-localization and characterization. We noted that 85% of these infrastructures are functional and in good condition (Figure 8).

For hydraulic infrastructures, it was noted that 90% of the water towers, 100% of the boreholes, and 75% of the standpipes observed are functional and in good condition. This physical condition of the facilities is corroborated by the observations of beneficiary households of which 92% confirm that the water supply systems are functioning and 88% consider their quality to

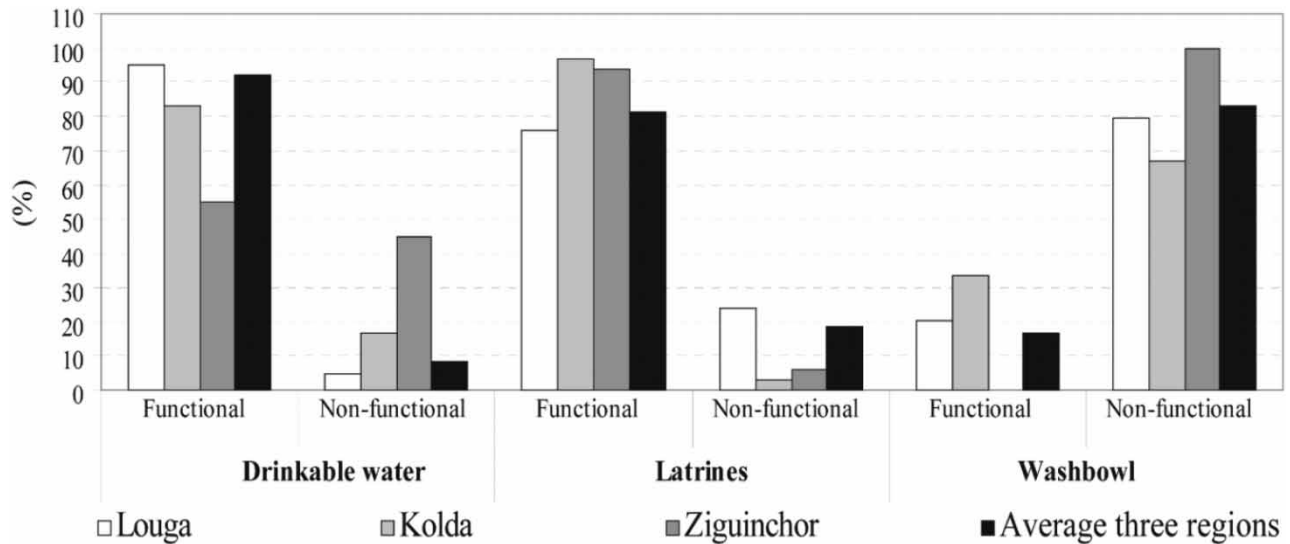


Figure 8 | State and quality of drinking water, sanitation and hygiene infrastructures achieved.

be satisfactory to very satisfactory. Concerning sanitation facilities, 81% of households assert that latrines are functional and in good condition, but only 53% consider their quality satisfactory to very satisfactory due to their poor technical adaptation (2%). For public latrines, 100% of the latrines surveyed were functional and in good condition, but it should be noted that this concerns rather those of coranic schools that are often well managed and maintained. As for handwashing facilities, only 17% of the beneficiary households reported that they were still functioning and being used due to lack of ownership and also the material quality of the infrastructure.

By promoting the establishment of a dynamic collaboration between several partners, the process of capacity-building and institutional development, as well as IEC actions, have been key success factors for the sub-program. IEC actions combined with training activities of community actors helped build the capacities of beneficiaries in managing the drinking water infrastructures and sanitation facilities installed. However, the technical, financial, and economic viability of the hydraulic facilities remains sustainable due to the continuity of the water supply service. Then, the maintenance or even consolidation of the WASH intervention impact on the economic and social transformation process in beneficiary localities will depend on the capacity to maintain the sustainability of the achievements, in which the governance system of the hydraulic facilities plays an important role.

However, the study has some methodological limitations regarding the project's effects assessment: (i) the first constraint is linked to the difficulty of measuring certain project effects in figures because the populations sometimes have difficulty in remembering the situation before the achievements; (ii) the second limitation relates to the effects of bias in analyzing the impact of the project on education and health, because of the implementation of educational programs (creation of schools in the villages and mass schooling) and health programs (vaccination, programs to fight diseases with epidemic potential).

CONCLUSION

For the first major initiative in rural Senegal, substantial investments were made in the short term to effectively and sustainably reduce the lack of access to drinking water and sanitation. These investments have had a considerable effect on improving the socio-economic, environmental and health conditions of the rural population, due to the efficacy and impacts of the WASH intervention. The sub-program achieved and sometimes exceeded its objectives in terms of physical achievements, with the quality of drinking water infrastructures being more satisfactory than the quality of sanitation facilities. Significant progress has been made towards achieving the MDGs and subsequent SDGs for WASH services in rural areas, with a significant increase in the proportion of households (on average 3 out of 4) with improved water sources and latrines. WASH investments targeted especially in the poorest regions of the country have made it possible to improve the households' living conditions and contribute to the achievement of development objectives in rural areas.

According to the experiences from several African countries that have benefited from the Rural Drinking Water and Sanitation Sub-Program, the results show that when the objectives in terms of interventions are achieved, the positive impacts on improving access to drinking water and sanitation services as well as in the socio-economic, environmental and health conditions of households are visible and very palpable. The study results show that the MDGs and SDGs have almost been achieved and sometimes even exceeded in the project intervention areas with indicators of access to drinking water and water sanitation above national rates and targets.

Hence, the direct, indirect, intermediate, and long-term effects have contributed significantly to the improvement of the socio-economic, environmental, and health conditions of the beneficiary communities by addressing several domains of sustainable development in a context of poverty growth and climate change, particularly in rural areas. The progress made by the project's achievements demonstrate that improvement in water access, sanitation, and hygiene access is one of the main drivers of change and transformation of household living conditions in rural areas, often explaining the priority given to this area of intervention within the implementation of the MDGs and SDGs.

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ETHICAL CONSIDERATIONS

The AfDB and the Government of Senegal had provided an introductory letter to inform communities about the study's objectives. Also, the households surveyed were subjected to clearance consent before the administration of the questionnaire.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

REFERENCES

- AfDB 2015 *Water Supply & Sanitation in Africa: Findings, Lessons and Good Practices to Improve Delivery*. African Development Bank Group, Independent Development Evaluation (IDEV), Evaluation reports & working papers, p. 70.
- AfDB 2016a *Évaluation d'impact du Programme d'approvisionnement en eau et d'assainissement en milieu rural au Sénégal 2006–2010 - Phase de lancement*. Rapport de synthèse, Groupe de la Banque africaine de développement, Évaluation indépendante du développement (IDEV), p. 68.
- AfDB 2016b *Impact Evaluation of Rural Water Supply and Sanitation Program in Ethiopia*. Draft Approach Paper, African Development Bank, p. 23.
- ANSD 2019 *Situation économique et sociale du Sénégal en 2016*. Rapport final, Agence Nationale de la Statistique et de la Démographie (ANSD), p. 372.
- Bartram, J. & Cairncross, S. 2010 Hygiene, sanitation, and water: forgotten foundations of health. *PLoS Medecine* 7 (11), 9.
- Cairncross, S., Bartram, J., Cumming, O. & Brocklehurst, C. 2010 Hygiene, sanitation, and water: what needs to be done? *PLoS Medecine* 7 (11), 7.
- Cerulli, G. 2014 *Treat-rew: a user-written command for estimating average treatment effects by reweighting on the propensity score*. *Stata Journal* 14, 541–561.
- Clasen, T. F. & Laurence, H. 2008 *Water Quality Interventions to Prevent Diarrhoea: Cost and Cost-Effectiveness*. Public Health and the Environment, World Health Organization (WHO), Geneva, p. 40.
- Darvesh, N., Das, J. K., Vaivada, T., Gaffey, M. F., Rasanathan, K. & Bhutta, Z. A. 2017 *Water, sanitation and hygiene interventions for acute childhood diarrhea: a systematic review to provide estimates for the Lives Saved Tool*. *BMC Public Health* 17 (Suppl 4), 776.
- Fewtrell, L., Kaufmann, R. B., Kay, D., Enanoria, W. & Haller, L. & Colford Jr., M. 2005 *Water, sanitation and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis*. *The Lancet Infectious Diseases* 5, 42–52.
- Hartinger, S. M., Lanata, C. F., Hattendorf, J., Verastegui, H., Gil, A., Wolf, J. & Meausezahl, D. 2016 Improving household air, drinking water and hygiene in rural Peru: a community-randomized-controlled trial of an integrated environmental home-based intervention package to improve child health. *International Journal of Epidemiology* 2016, 1–11. doi: 10.1093/ije/dyw242.
- Huber, C. 2015 *Introduction to Treatment Effects in Stata: Part 1. The Stata Blog: Not Elsewhere Classified*. Available from: <http://blog.stata.com/2015/07/07/introduction-to-treatment-effects-in-stata-part-1/>.
- Hunter, P. R., MacDonald, A. M. & Carter, R. C. 2010 Water supply and health. *PLoS Medecine* 7 (11), 9.

- Joshi, A. & Amadi, C. 2013 Impact of water, sanitation, and hygiene interventions on improving health outcomes among school children. *Hindawi Publishing Corporation Journal of Environmental and Public Health* **2013**, 10. Article ID 984626. <http://dx.doi.org/10.1155/2013/984626>.
- McMichael, C. 2018 [Water, sanitation and hygiene \(WASH\) in schools in low-income countries: a review of evidence of impact](#). *International Journal of Environmental Research and Public Health* **16** (3), E359. doi:10.3390/ijerph16030359.
- MHA 2016 Revue conjointe sectorielle de l'eau et de l'assainissement. Rapport de présentation, Ministère de l'Hydraulique et de l'Assainissement (MHA).
- Mills, J. E. & Cumming, O. 2016 *The Impact of Water, Sanitation and Hygiene on Key Health & Social Outcomes*. Review of evidence paper, UNICEF, UKAID, LSHTM, p. 112.
- Null, C., Pickering, A. A., Stewart, C., Lin, A., Njenga, S., Colford, J., Arnold, B., Dewey, K., Fernald, L. & Kariger, P. 2018 *WASH Benefits: The Effects of Water Quality, Sanitation, Handwashing, and Nutrition Interventions on Child Health, Growth, and Development in Rural Kenya*. Innovations for Poverty Actions (IPA), Study summary of policy issue, p. 5.
- Piper, J. D., Chandna, J., Allen, E., Linkman, K., Cumming, O., Prendergast, A. J. & Gladstone, M. J. 2017 Water, sanitation and hygiene (WASH) interventions: effects on child development in low- and middle-income countries. *Cochrane Database of Systematic Reviews* **3**, CD012613. doi:10.1002/14651858.CD012613.
- Ramesh, A., Blanchet, K., Ensink, J. H. J. & Roberts, B. 2015 [Evidence on the effectiveness of water, sanitation, and hygiene \(WASH\) interventions on health outcomes in humanitarian crises: a systematic review](#). *PLoS One* **10** (9), e0124688. doi:10.1371/journal.pone.0124688.
- Tamboura, S., IssaLende, M. & Pantella, L. 2019 Impact evaluation of WASH in nutrition intervention on morbidity and acute malnutrition in Niger. *Field Exchange* **59**, 4.
- Taylor, D. L., Kahawita, T. M., Cairncross, S. & Ensink, J. H. J. 2015 [The impact of water, sanitation and hygiene interventions to control cholera: a systematic review](#). *PLoS One* **10** (8), e0135676. doi:10.1371/journal.pone.0135676.
- UNICEF-WHO 2015 *25 ans of Progress on Sanitation and Drinking Water – 2015 Update and MDG Assessment*. Joint Monitoring Programme (JMP), UNICEF and World Health Organization (WHO), Geneva, Switzerland, p. 90.
- UNICEF-WHO 2019 *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2017. Special Focus on Inequalities*. United Nations Children's Fund (UNICEF) and World Health Organization (WHO), New York, p. 140.
- UN-Water_WHO 2019 *National Systems to Support Drinking-Water, Sanitation and Hygiene: Global Status Report 2019. UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) Report*. Licence: CC BY-NC-SA 3.0 IGO. World Health Organization, Geneva.
- USAID 2017 *Real Impact West Africa Water Supply, Sanitation and Hygiene Program*. United States Agency for international Development (USAID), summary report, p. 4.
- USAID 2019 *Evaluation Ex post du programme d'eau potable et d'assainissement du millénaire au Sénégal (PEPAM/USAID)*. Résumé analytique, rapport d'évaluation, p. 10.
- WHO-UNICEF 2015 *Water, Sanitation and Hygiene in Health Care Facilities: Status in Low- and Middle-Income Countries and Way Forward*. ISBN 978 92 4 150847 6.
- Wolf, J., Pruss-Ustun, A., Cumming, O., Bartram, J., Bonjour, S., Cairncross, S. & Higgins, J. 2014 [Assessing the impact of drinking water and sanitation on diarrhoeal disease in low-and middle-income settings: systematic review and meta-regression](#). *Tropical Medicine and International Health* **19** (8), 928–942.
- World Bank 2018 *Findings of the Mozambique Water Supply, Sanitation, and Hygiene Poverty Diagnostic*. WASH Poverty Diagnostic. World Bank Group, Washington, DC, p. 91.
- WSP- World Bank 2012 *Impacts socio-économiques d'un mauvais assainissement en Afrique. Etude documentaire sur la Mauritanie*. Water and Sanitation Program, World Bank Group, p. 6.

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