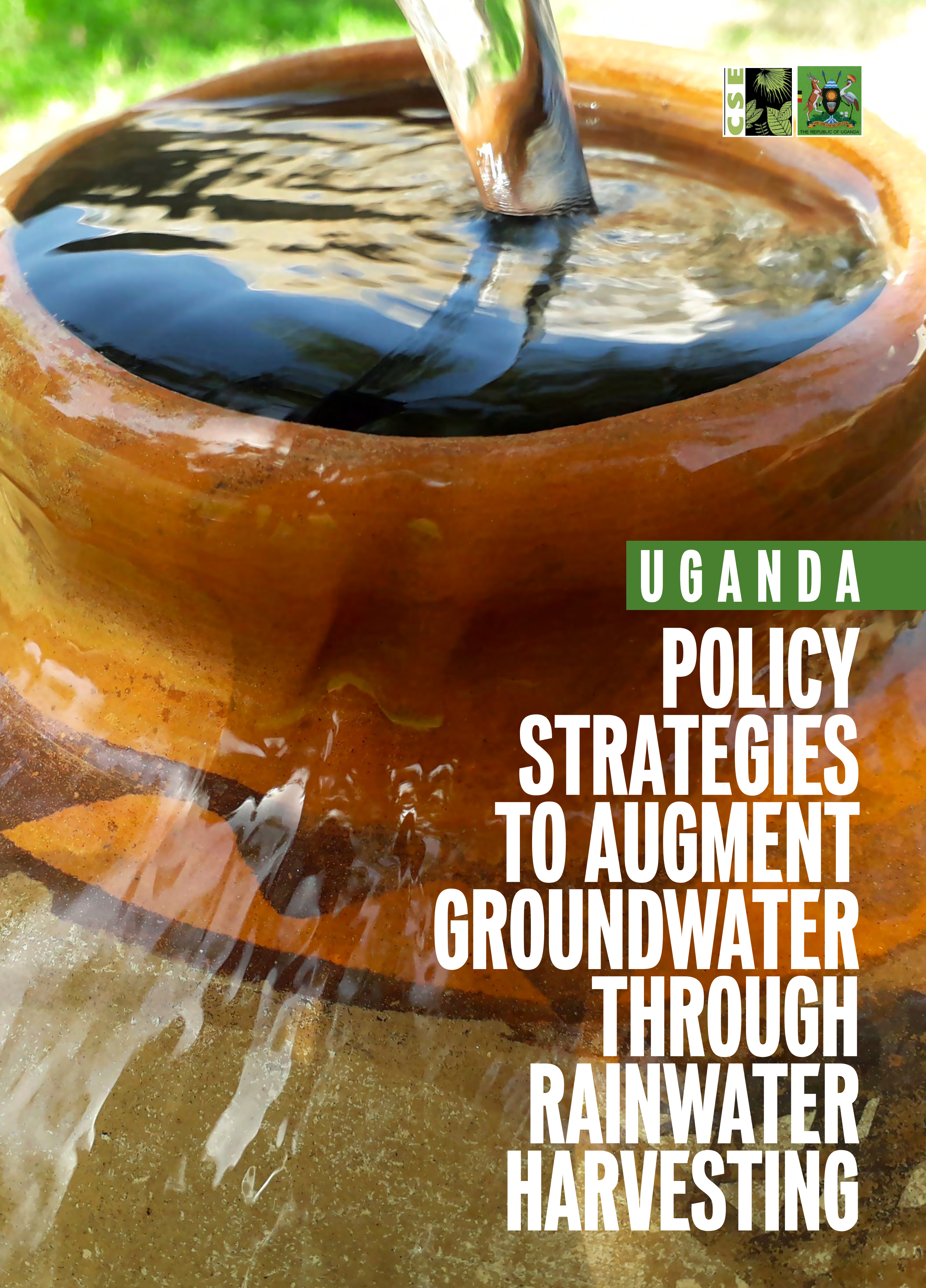

UGANDA

POLICY STRATEGIES TO AUGMENT GROUNDWATER THROUGH RAINWATER HARVESTING

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1. Introduction

- Water supply in Uganda—both surface and groundwater—is rainwater-based.
- More than 75 per cent of the population live in rural areas and depend to a large extent on groundwater reserves.
- Uganda currently has sufficient groundwater reserves except in a few areas in the northeast and southwest. The high rate of urbanization, loss of waterbodies and variability of rainfall have raised questions about the efficiency of natural recharge of groundwater in the country.
- To make the source sustainable, Uganda needs policies that focus on groundwater recharge through technological interventions that are community centric.
- Strong communication strategies should be formulated to make communities aware about water conservation.

Uganda, a landlocked country, occupies 241,550.7 km^2 of land (see *Map 1: Districts of Uganda*). The country is endowed with abundant water sources. Open water and swamps constitute 41,743.2 km^2 of area. In other words, about 16 per cent of the total land area comprises wetlands and open water. Uganda receives annual water supply of 66,000 million cubic metres (MCM) in the form of rain and inflows.[1]

Since direct rainfall is the most important source for water resources in Uganda, understanding the spatial and temporal variability of rainfall is paramount when assessing water availability. As in any other country, water availability in Uganda determines the local water resources, land-use potential and population distribution.

Uneven geographical distribution of rainfall, along with pressures from rapid population growth, increased urbanization, industrialization and environmental degradation, are a big challenge to the sustainable development of the country's freshwater resources. As of June 2010, Uganda's mid-year population was estimated at 31.8 million. Of this, 14.8 per cent (4.7 million) lived in urban areas and 85.2 per cent (27 million) in rural areas.[2] According to the 2019 Joint Monitoring Progress Report published by the United Nations Children's Fund (UNICEF) and World Health Organization (WHO), however, 77 per cent of Uganda's population lived in rural areas.[3] The rate of annual growth of population is 3.4 per cent, among the highest in the world. This high rate of increase in population poses a major challenge in increasing safe-water coverage.[4]

The largest supply of water for rural Uganda comes from spring water, followed by boreholes, shallow wells with hand pumps. Groundwater reserves are hence the main source of supply for rural areas. Gravity-flow water, surface water and stored rainwater also supply water to villages and small towns that are categorized as rural.

The increase in demand for water supply in Uganda as a result of high population growth as well as agricultural and industrial expansion has triggered unplanned groundwater development and use in many parts of the country. This has put future

Map 1: Districts of Uganda

Source: Sushmita Sengupta and Sristhi Anand, 2020, Uganda: Improving the State of Sanitation, Centre for Science and Environment, New Delhi.

yield and sustainability of groundwater abstraction in some parts into question, especially in the north-eastern and south-western parts, where natural recharge of groundwater is low compared to the rest of the country. There are reports of poor-quality groundwater mainly due to inadequate sanitation facilities—in many areas high nitrate and bacteriological contamination of groundwater have been reported. High fluoride and iron and manganese above permissible limits have also been found in the groundwater due to natural reasons, impacting public health and the economy of Uganda.

It has been noted that there has been a reduction in the area and quantity of water in waterbodies, the big recharge bodies in the country, thereby reducing the chances of natural groundwater recharge. The recharge of the groundwater improves both quality and quantity of the reserve. Rural areas need to implement groundwater recharge structures efficiently as more than 90 per cent of the rural water schemes are groundwater dependant. Wherever the quality of groundwater is affected by the poor quality of sanitation, insanitary toilets should be converted to sanitary ones and black and grey water should be treated.[5]

Strong communication strategies should be designed to make households and the communities aware about water conservation. Communities should be involved in such projects from the planning to the implementation stage. Traditional and small water-harvesting systems should be promoted. Reuse of treated wastewater for non-potable purposes should also be focused on.

Uganda has no dearth of groundwater reserves except in a few dry patches in the north-west and south-eastern parts. In view of the growing demand for water, high rate of urbanization that is hindering natural recharge of groundwater, loss of waterbodies and, most importantly, variation in rainfall trends due to climate change, the big question is whether groundwater sources will remain sustainable.

There are several water policies and strategies in Uganda with regard to groundwater reserves. But we need policies to protect the sponges (waterbodies) not only to recharge the groundwater but also to protect areas from flash floods. The policies should focus on technological interventions to recharge groundwater to make the sources of groundwater—spring water, borewells and shallow wells—sustainable for the future.

2. Management of water sources in Uganda: Overview

- Water sources include large lakes, wetlands, rivers, surface runoff and groundwater.
- There are eight drainage sub-basins, whose yield is significant.
- Uganda has a highest rate of urbanization in Africa. Demand for water is thus ever-increasing.
- Due to increase in water demand, supply from the water utilities had to increase by 51 per cent in just eight years between 2002–03 and 2010—49 per cent of this demand is for households.
- Over 75 per cent of domestic areas are rural and depend on borewells, shallow wells and spring water sourced from groundwater.
- A decline of wetland coverage in the country by almost 2 per cent in the last decade mainly in the Lake Victoria and Kyoga drainage basins, where major groundwater reserves can be found, has lead to low groundwater recharge potential.
- In spite of enormous water resources, a few areas of the country face long dry spells mainly due to temporal and spatial variability of rainfall.

Water resources in Uganda comprise large lakes, including Lakes Victoria, Kyoga, Albert, George and Edward; wetlands and rivers such as the Nile River, Katonga, Semliki and Malaba; rainfall; surface water runoff and groundwater.

All of Uganda's water resources are part of the Nile. Uganda is a downstream riparian to Burundi, Democratic Republic of Congo (DRC), Kenya, Tanzania and Rwanda and an upstream riparian to South Sudan, Sudan and Egypt.

Several issues and challenges surround Uganda's water resources, aggravated by factors such as climate change, variability of rainfall and population growth. Uganda's current water management practices may not be robust enough to cope with these challenges, which impact water resources and increase requirements for water use. With a rapidly growing population and improving living standards, the pressure on its water resources is increasing and per capita availability of water resources falling. Further, spatial and temporal variability in precipitation often result into floods, landslides and droughts. Climate change is expected to impact rainfall and water availability.

The Department of Water Resources Management of Uganda has divided surface-water resources into eight main drainage sub-basins. The sub-basins include Lake Victoria, Lake Kyoga, River Kafu, Lake Edward, Lake Albert, River Aswa, Albert Nile and Kidepo Valley. Their yield, though small compared to the total flow from the Nile, dominates the water resources potential within Uganda. Major waterbodies include Lakes Victoria, Kyoga, Albert, George, Edward and another 149 smaller lakes, all of which cover an area of 38,500 km^2.

The most prominent hydrological feature in Uganda is Lake Victoria, the second-largest freshwater lake in the world, with an area of 69,000 km^2. The river Nile is the only outflow from the lake. Because of warping of the landscape, many of the perennial streams of the plateau are clogged with swamps. About 10 per cent of the country is covered by swamps (wetlands), of which one-third is permanently inundated. In the south and west of the country, swamps form an extensive low-gradient drainage system in steep V-shaped valley bottoms with a permanent wetland core and relatively narrow seasonal wetland edges. In the north, swamps comprise mainly broad floodplains. In the east they exist as a network of small, vegetated valley bottoms in a slightly undulating landscape.

The wetlands, another significant water source, and groundwater recharge bodies in the country show two broad distributions of wetland ecosystems in Uganda—one, the natural lakes and lacustrine swamps found around major lakes and, two, the riverine and floodplain wetlands associated with the major river systems in Uganda. The wetlands covered about 29,000 km^2, or 13 per cent of the total area of the country in the late 1990s. By 2008, the figure fell to 10.9 per cent.[6] According to a 2014 study,[7] this decline was generally observed around the Lake Victoria and Kyoga drainage basins, where high groundwater resources can be observed (see *Table 1: Average groundwater resource in the major basins* in Chapter 3). According to a 2011 Ministry of Water and Environment performance report of the water and environment sector in Uganda,[8] the decline in groundwater is largely attributed to encroachment for expansion of urban centres, settlements, industrial development and extension of agricultural land. Except for Sango Bay, the bulk of Uganda's wetlands lack legal protection. Despite Uganda's significant water resources, their spatial and temporal variability often renders many parts of the country water-stressed for long periods during the year.

The Directorate of Water Development (DWD) and National Water and Sewerage Corporation (NWSC) have been tasked to ensure that water is available to Ugandans. Available information from NWSC shows that there has been a steady increase in total water production from 46.7 million m^3/year in 2000–01 to 72.14 million m^3/year in 2009–10. A comparison of water requirement with available renewable freshwater showed that Uganda had the capacity to utilize only 1 per cent of its current renewable freshwater. Of the total water withdrawal, domestic water supply accounted for about 51 per cent, agriculture 41 per cent and industry 8 per cent.

Uganda has one of the fastest-growing populations—3.2 per cent annually—in Africa. Consequently, according to NWSC annual reports, total revenue water—water supply that is metered and charged—increased from 31,151,380 MCM/year in 2002–03 to 47,027,817 MCM/year by June 2010. Much of the total water produced was supplied to domestic consumers (48.9 per cent) and industrial and commercial enterprises (25.4 per cent). The major water source exploited was groundwater extracted from protected springs, deep boreholes and shallow wells.

3. Status of water supply in rural Uganda: Role of groundwater

- More than 90 per cent of the rural water supply is through groundwater.
- Districts around the Victoria Nile and Kyoga basins have the most groundwater reserves. The Kidepo basin has the least.
- Around 1,200 tube wells and 900 shallow wells are constructed annually in Uganda.
- Natural groundwater recharge is low in areas where rainfall is low—the north-east and south-west of the country.
- This may not currently be a limiting factor for groundwater. Government reports, however, indicate that this issue may grow in the near future.
- Government's own assessment shows that there may be groundwater decline in localized areas due to climate change, changes in land use—especially deforestation, unsustainable water withdrawals due to unplanned urbanization and poor catchment management—prolonged droughts and reduced rainfall in catchments.

Groundwater is the primary source of freshwater for drinking and irrigation around the world. It supplies 75 per cent of all safe sources of drinking water in Africa. In Uganda, for example, 61 per cent of the country's water is from groundwater sources accessed from springs and boreholes around Lake Victoria and south-western Uganda. Several studies[9] have assessed groundwater occurrence in Uganda from different perspectives, mostly at the catchment scale. These assessment studies have been the basis for planning of water resources in the country.

The Victoria Nile River and Kyoga basin have sustainable groundwater (see *Table 1: Average groundwater resource in the major basins*)—more than 36 mm/year—while the Kidepo River has the least amount of sustainable groundwater, equivalent to 6.3 mm/year.

Groundwater is the major source of water supply in rural Uganda, including in semi-arid and arid areas. It is generally found in weathered or fractured basement rocks and has a yield of 0.5–80 m^3 per hour. There has been groundwater use since the 1930s through the construction of deep boreholes, shallow wells and protected springs. On average, 1,200 tubewells and 900 shallow wells are constructed annually in Uganda. Approximately 40,000 deep boreholes, 16,000 shallow wells and 30,000 protected springs have been constructed in the country mainly for rural domestic water supply.[10] Boreholes and shallow wells are normally installed with handpumps.

Uganda receives fairly high rainfall except in parts of north-eastern and south-western regions (see *Map 2: Mean annual rainfall in Uganda*). Natural groundwater recharge in Uganda is also quite high except in areas that receive

Table 1: Average groundwater resource in the major basins

River/lake basin	Annual groundwater resource (mm/year)	Annual groundwater resource (million cubic meters [MCM]/year)
Lake Edward	20.3	362
Lake Victoria	24.7	813
Lake Albert	23.7	353
Victoria Nile	39.9	1110
Lake Kyoga	36.1	1946
Albert Nile	24.4	500
Aswa	17.3	478
Kidepo	6.3	20
Miscellaneous	15.0	85

Source: Ministry of Water and Environment, 2013. National Water Resource Assessment Report.

low rainfall (see *Map 3: Estimated groundwater recharge in Uganda*) compared to current volumes of groundwater abstraction—water removed from aquifers without considering return flows or leakage—and will not be a limiting factor in groundwater development for a few years. There is, however, a need to carry out more detailed recharge and water balance studies in the country to ensure that groundwater development is carried out in a sustainable manner.

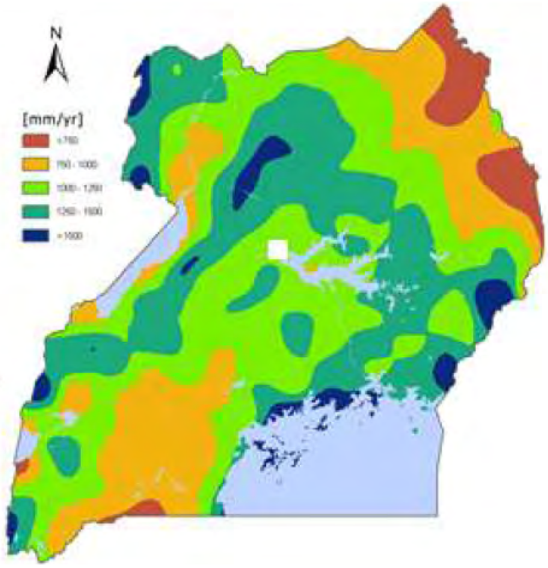
The Government of Uganda started an assessment of groundwater in 1996 to fully understand the nature, extent and reliability of the country's groundwater resources. The study provided information on the distribution and behaviour of aquifers, groundwater recharge, aquifer vulnerability to pollution and impact of motorized abstraction on groundwater resources. A conceptual model of groundwater dynamics has also been developed.

Reports in early 2000 about groundwater assessments in three catchments—namely Ruizi, Wamala and Victoria—concluded that groundwater resources were declining.[11] According to a report of the monitoring and assessment department of the Directorate of Water Resources Management (DWRM), the causes of decline include global warming, changes in land use, especially deforestation, unsustainable water withdrawals, poor catchment management, prolonged droughts, reduced rainfall in the catchment.

According to the latest (2013) government report,[12] in 2009 the demand in some parts of south-east Uganda was very high. These areas coincided those showing low recharge (see *Map 4: Estimated groundwater demand per district in 2009*).

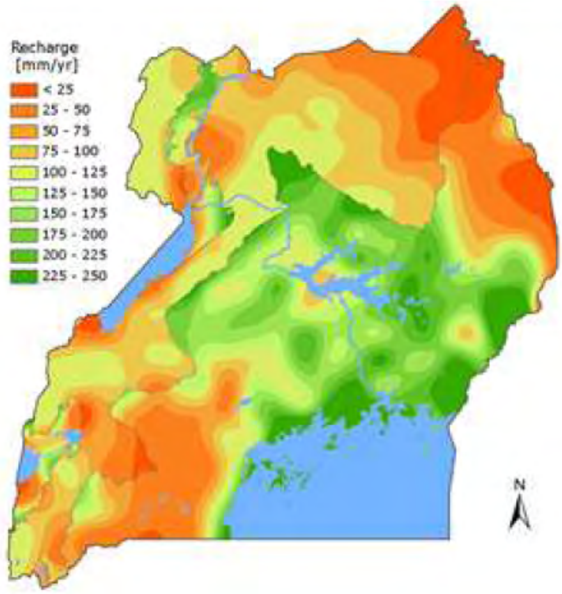
Data from the latest assessment report[13] suggests that by 2030 demand for domestic water in rural areas and small towns can safely be met by groundwater in most of the country where the utilization rate is less than 15 per cent (see *Map 5: Sustainable rates per district of groundwater utilization projected to 2030*). Exceptions include Wakiso, which is undergoing rapid urbanization in the vicinity of Kampala, as well as the Kampala–Entebbe corridor. It is, however, likely that by 2030 these newly urbanized areas will be supplied by the Directorate of Water Resources Management with water from Lake Victoria in which case the use of groundwater will be substantially lower than suggested by this study. The demand for groundwater should not increase in Jinja since water pumped from Lake Victoria is an obvious alternative source or in Mbale where gravity-based

Map 2: Mean annual rainfall (mm) in Uganda



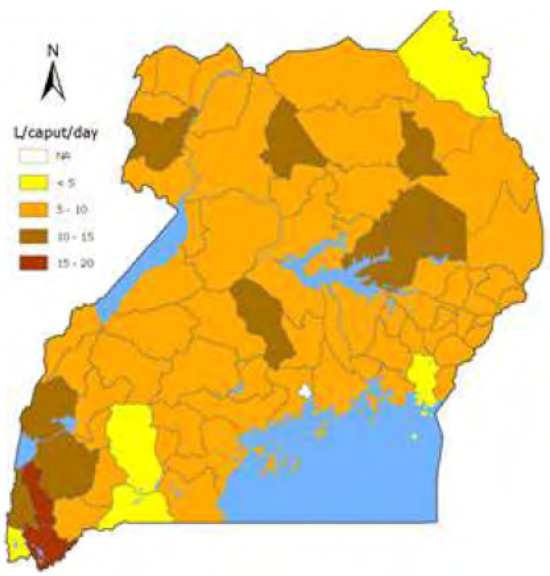
Source: Ministry of Water and Environment, 2013. National Water Resource Assessment Report.

Map 3: Estimated groundwater recharge (mm) in Uganda



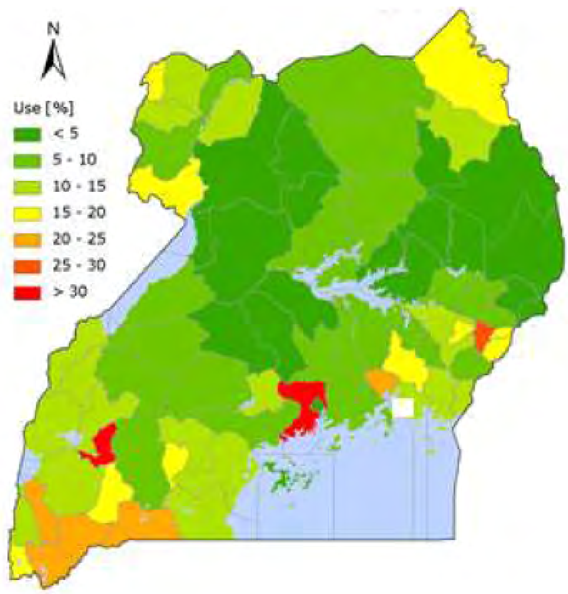
Source: Ministry of Water and Environment, 2013. National Water Resource Assessment Report.

Map 4: Estimated groundwater demand per district in 2009



Source: Ministry of Water and Environment, 2013. National Water Resource Assessment Report.

Map 5: Sustainable rates per district of groundwater utilization projected to 2030 (expressed as the proportion [%] of available resources)



Source: Ministry of Water and Environment, 2013. National Water Resource Assessment Report.

systems from Mount Elgon could be used. Utilization rates are expected to be high in Ibanda (30 per cent of the groundwater by 2030), a small district with a high population density and unfavourable geomorphological conditions, and in a cluster of districts in south-western Uganda, where groundwater utilization rates of around 20–25 per cent are projected. Although these districts do not currently face acute water shortages, some sub-counties may experience them in the future.

The 2013 report[14] also added that the estimated renewable groundwater resource exceeded the projected demand for domestic water but shortages may arise at the local scale, particularly for areas with high population density.

4. Challenges due to poor quality and scarcity of groundwater

- Uganda's groundwater reserves are fairly good except for localized areas in the north-east and south-west. But the reserve will fall in the near future because of the reduction in natural groundwater recharge.
- The quality of groundwater is a major concern.
- Groundwater is contaminated due to natural mineralization and anthropogenic causes.
- To protect groundwater from bacteriological contamination, poor management of faecal sludge due to faulty toilet design has to be tackled by the country on a war footing.
- Natural mineralization causes high concentrations of iron, manganese and fluoride in groundwater.
- High mineralization of groundwater may cause health hazards, damage plumbing systems and even make the water non-potable.
- Several policies and strategies in Uganda deal with the threat of quantity and quality of the groundwater and protection of water sources.
- Implementation of these policies and strategies needs a mix of engineering solutions, capacity building and behaviour change of stakeholders.

The scarcity of the groundwater is confined around the north-east and south-west of Uganda due to which the communities here use surface water. As per the Joint Monitoring Progress Report of 2019, use of surface water is only 3.80 per cent of total water consumption.[15] According to the reports,[16] communities can currently manage with available groundwater resources but reserves may soon fall due to variability of rainfall, degradation of the catchment, deforestation and urbanization. Due to both natural and anthropogenic causes, the country faces the challenges of poor quality of groundwater.

Important existing policies, strategies and actions related to groundwater include Acts such as the Water Act, Cap 152, the Environment Act, and policies and strategies such as the Water Policy and the Framework and Guidelines for Water Source Protection.

Health and socio-economic impact

Uganda is divided into 14 sub-regions with regard to monitoring health services. Sanitation is a category in all 14 sub-regions. Poor sanitation conditions in Uganda adversely impact the quality of groundwater, economic growth and human development.[17]

The high burden of sanitation-related diseases is especially common in Uganda as most of the population has limited access to protected water sources and adequate sanitation facilities. The government has estimated that around 64 per cent of the rural population has access to safe water.[18] Despite this, many rural areas rely on contaminated water sources and are supplied water from contaminated groundwater, streams, spring wells, ponds and lakes.

The deterioration in the quality of both surface and underground water is to a large extent because of inadequate sanitation facilities.[19] An Ecological Christian Organization in Bugiri Town Council publication showed that faulty pit toilets can contaminate groundwater and spring water. High levels of faecal streptococcus—up to 2,200 colony forming unit (cfu)/100 ml in bore well water and 1,350 cfu/100 ml in spring water—were observed as against a permissible limit of 0 cfu/100 ml as per World Health Organization. Cases of waterborne diseases in 2018–19 showed that malaria was the leading cause of illness for all ages, accounting for 12.5 per cent, and diarrhoea contributed to 1.6 per cent of all OPD attendances. It is noteworthy that around 0.8 million children under the age of five were reported for diarrhoea in 2018–19 (see *Table 2: Cases of diarrhoea and malaria in OPD attendance in 2018–19*). Analysis of cases of diarrhoea in the country for 2000–16 shows, however, that the number of cases declined over sixteen years (see *Figure 1: Cases of diarrhoea reported in Uganda in 2000–16*) although the number of cases remained fairly high during this period.

An assessment of diarrhoea cases in 2011–16 shows an alarming 11,030 cases. The highest number of cases were 6,226 in 2012 and the lowest were 229 in 2011 (see *Figure 1: Cases of diarrhoea reported in Uganda in 2000–16*). Around 33 per cent of the districts, which accounted for 40 per cent of the population of the country, were affected in every study year at least once.[20]

Table 2: Cases of diarrhoea and malaria in OPD attendance in 2018–19

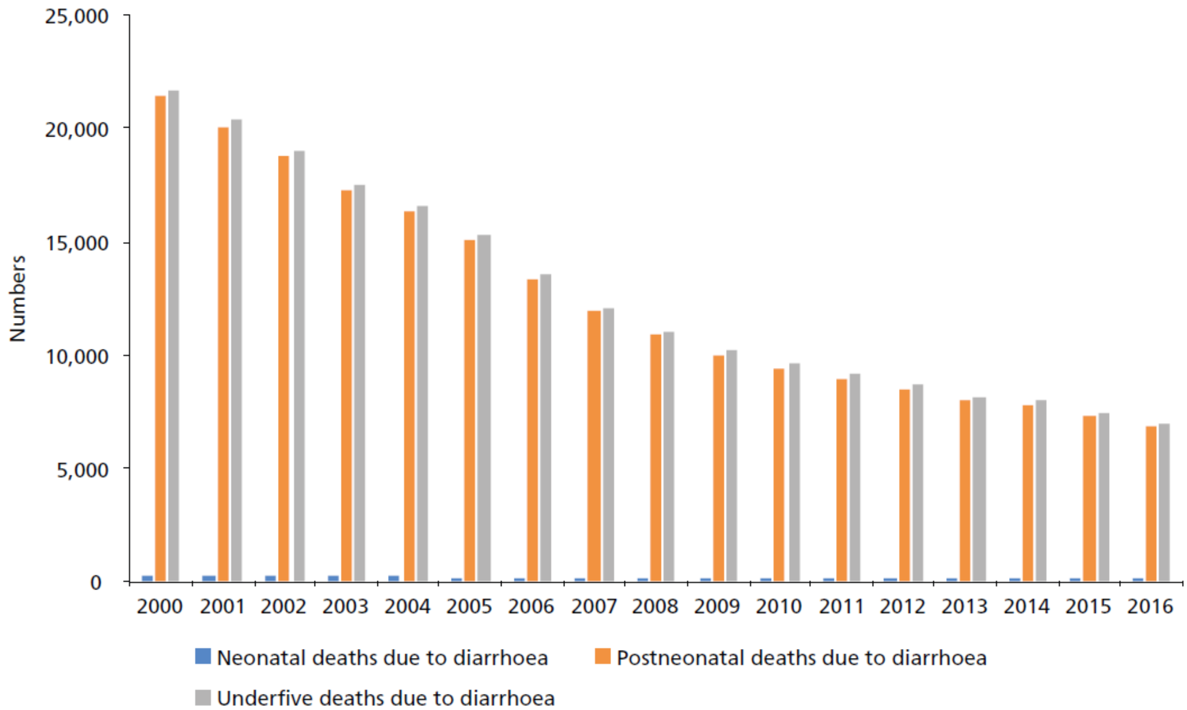
	Cases under five years of age	Cases of five years of age and above	Percentage contribution to total
Diarrhoea	796,752	560,670	1.6
Malaria	2,647,223	7,836,189	12.5
Others (including diarrhoea and malaria)	9,501,554	74,653,778	100

Source: Sushmita Sengupta and Sristhi Anand, 2020, Uganda: Improving the State of Sanitation, Centre for Science and Environment, New Delhi

Contamination of groundwater in Uganda occurs also because of natural mineralization due to which the groundwater shows high concentrations of iron, manganese and/or chloride. The concentration of iron in groundwater is often high and above the WHO guideline of 0.3 mg/l for drinking water. The presence of iron is determined by the mineral composition of the aquifer and the extent to which minerals containing iron are dissolved in the water. Elevated iron content does not have serious health implications but may give the water an unpleasant taste and cause discolouration of clothes and utensils.

Manganese rarely occurs at concentrations >1 mg/l, but its presence can cause an unpleasant taste and damage laundry and plumbing fixtures. High fluoride concentrations are characteristic of volcanic settings, and the problem is enhanced by the relatively high solubility of most fluoride minerals. Local variations can be considerable and significant variations in fluoride content can occur in boreholes within short distance of each other. Fluoride concentrations in drinking water in excess of 2 mg/l may cause discolouration and mottling of

Figure 1: Cases of diarrhoea reported in Uganda in 2000–16



Source: Sushmita Sengupta and Sristhi Anand, 2020, Uganda: Improving the State of Sanitation, Centre for Science and Environment, New Delhi.

teeth (dental fluorosis), while long exposure to high concentrations (6–8 mg/l) can lead to skeletal fluorosis. Chloride content of up to several thousand mg/l are found in some locations—concentrations in excess of 500–700 mg/l make the water undrinkable as well as unsuitable for irrigation. The exact cause of such high chloride levels is unknown but it might reflect low infiltration and high evapotranspiration rates, leading to the formation of brines. Geological factors, such as volcanic rocks with high chloride content or saline soils, may also have some influence.

The latest Ministry of Water and Environment groundwater quality report of 2013[21] **shows that total coliform exceeded the WHO limit in 66 per cent of the samples** (**see** *Table 3: Groundwater quality information—frequency with which groundwater exceeds WHO standards*)**. While WHO recommends nil coliform in groundwater, Uganda allows the presence of some coliform (10 units)—the proportion of samples that exceeded the WHO criteria was fairly high.**

Groundwater that is turbid and shows high concentrations of iron is fairly common in most districts in Uganda (see T*able 4: Groundwater quality in some districts where parameters exceed WHO standards*).

Table 3: Groundwater quality information—frequency with which groundwater exceeds WHO standards

Parameters	Number of sources studied	Proportion that exceeds WHO criteria (%)	Proportion that exceeds maximum limit allowed by the country (%)
Total hardness	2,683	3	1
Total iron	1,524	38	7
Manganese	2,505	6	0
Turbidity	2,604	45	18
TDS	2,513	2	1
Fluoride	2,235	6	1
Nitrate	2,403	18	No criteria mentioned
Total coliforms (borewells)	171	38	28
Total coliforms (wells)	73	66	60

Source: Ministry of Water and Environment, 2013. National Water Resource Assessment Report.

Table 4: Groundwater quality in some districts where parameters exceed WHO standards

S. no.	District	Parameters exceeding WHO limits
1	Bugin	F, Mn, NO_3, pH, TDS, TH, Fe
2.	Busia	F, Mn, NO_3, pH, TDS, TH, Fe
3.	Iganga	F, Mn, NO_3, pH, TDS, TH, Fe, Turb
4.	Isingoro	Fe, Turb
5.	Jinja	Mn, NO_3, TH, Turb
6.	Kalim	TDS, TH
7.	Kanuli	Mn, Fe, Turb
8.	Kapchorwa	NO_3
9.	Kibaale	pH, Fe, Turb
10.	Kiruhura	Fe
11.	Kyenjojo	Fe, Turb
12.	Manafwa	F
13.	Masaka	pH, Fe, Turb
14.	Mayuge	F, Mn, NO_3, TDS, TH, Fe
15.	Mbale	F, Mn, NO_3, TH, Fe, Turb
16.	Mbarara	pH, TH, Fe
17.	Mityana	Ph, Fe, Turb
18.	Mubende	TH, Fe, Turb
19.	Mukono	NO_3, TH, Fe, Turb
20.	Namutumba	TDS, TH
21.	Pallisa	F, Mn, NO_3, pH, TDS, TH, Fe
22.	Rakai	pH, Fe, Turb
23.	Sironko	F, Mn, NO_3, TDS, Turb
24.	Tororo	F, Mn, NO_3, pH, TH, Fe
25.	Wakiso	Turb

Note: F = Fluoride, Fe = Iron, Mn = Manganese, NO3 = Nitrate, TH = Total hardness, Turb = Turbidity, TDS = Total dissolved solids

Source: Ministry of Water and Environment, 2013. National Water Resource Assessment Report.

State of groundwater in rural areas: Existing policies, strategies and actions

The main regulations under the Water Act that cover groundwater protection are the Water Resources Regulations (1998) and the Waste Discharge Regulations (1998). Similarly, the main regulations under the Environment Act that mention protection of groundwater sources are the Environmental Impact Assessment Regulations (1998), the National Environment (Standards for Discharge of Effluent into Water or on Land) Regulations (1999), and the National Environment (Waste Management) Regulation (1999).

The Directorate of Water Development (DWD) and the Directorate of Water Resources Management (DWRM) under the Ministry of Water and Environment (MWE) are mandated to develop and manage water resources in the country. DWD is responsible for water development and water service regulation in urban areas. DWRM is responsible for implementing national water laws, policies, plans and regulations; monitoring water quality and quantity; and management of transboundary water resources.

In 2013, MWE also published in two volumes *Guidelines for Protecting Water Sources for Piped Water Supply Systems,* which examines threats to groundwater quantity and quality. Control measures such as reducing deforestation and improvement of sanitation facilities were suggested to improve groundwater quantity and quality. The guidelines look into catchment protection as well.

Water Source Protection Guidelines were developed as part of a wider programme of operationalizing Integrated Water Resource Management (IWRM) throughout Uganda. The aim was to reduce degradation of surface and groundwater resources that impacts the health and livelihoods of millions of Ugandans, damages the economy and biodiversity of the country as a whole and creates risk of conflict with neighbouring countries that share transboundary water resources.[22]

Since the non-governmental organizations (NGOs), community-based organizations (CBOs) and faith-based organizations (FBOs) play an important role as implementers for water supply, they need to prepare plans for the protection of water sources, mainly groundwater. They are also expected to implement the plans.

Delivering effective source protection is a complex process that in many cases require a mix of engineering solutions, training and behaviour change. To do this successfully, stakeholders in the catchment are likely to need external support in terms of access to funding, training, and technical advice on issues such as sanitation improvement, improved agricultural skills and practices. This support may come from mandated government institutions, international development partners and NGOs.[23]

5. Suggested action plans to augment groundwater sources through rainwater harvesting

- The government of Uganda has always promoted rainwater harvesting to store rainwater.
- Technological options for groundwater recharge need to be sought as Uganda faces a problem of decline of natural groundwater recharge.
- Other initiatives of water conservation such as reuse of wastewater, renovation and restoration of traditional water-harvesting structures and demand-side management should be included in policies and strategies related to groundwater.
- A water quality and surveillance programme is required.
- All such programmes and policies for groundwater recharge, monitoring and evaluation should be community-centric.
- Communities should be made aware of the issues and solutions through well-developed information and communication strategies.

Rural Uganda's water supply is largely groundwater-based. Clean and steady sources of water through the year are essential for the rural population. There is no dearth of groundwater in areas that do not have piped-water supply, but there may be local water shortages due to high density of population and poor quality of groundwater.[24] A 2013 assessment of national water resources showed that the average rain deficit is less than 200 mm/year in about 20 per cent of Uganda, while 35 per cent has a deficit of 200–400 mm/yr. The average annual deficit in the north-east and parts of the Rift Valley exceeds 600 mm.[25] This can affect groundwater recharge.

To achieve sufficient quantities of clean water through the year, judicious use of available water along with water-conservation measures should be taken up. Many villages face water scarcity not only due to long spells of drought but also due to contaminated sources of water. It is important to ensure sustainability of sources of water through effective management of demand and supply of water.

According to the government's own report,[26] the projected rate of groundwater use is relatively high in several districts in south-western Uganda. The report says that there is currently no acute shortage but that these districts are approaching a critical situation where groundwater availability in some sub-counties may require special attention. In the absence of sufficient data, the report suggests ban of groundwater use for purposes other than drinking. The main reason for this crisis is limited awareness about the methods of augmentation of groundwater and poor community participation in water security plans at the village level.

Judicious use of available water and water conservation measures are important to ensure water security. Ensuring sustainability of sources for districts such as those in south-west Uganda by effectively managing the demand and supply of water is of utmost importance.

A source is considered sustainable only when it delivers desired quantities of safe water through the year. Sustaining a source for water supply requires specific interventions for source sustainability, optimal use and management of water sources. To strengthen the source of water, there is a need to prepare a budget—with an assessment of the amounts of water available and analysis of its demand and supply.

The most practised mode of rainwater harvesting is storing rooftop rainwater. According to a 2013 government report, the government has for long placed little emphasis on this type of rainwater harvesting as preference was accorded to the construction of springs, shallow wells, deep boreholes and piped-water supply.[27] It is now, however, being recognized as one of the key solutions to providing accessible and safe water, particularly in rural areas. There is a deliberate effort by the Ministry of Water and Environment (MWE) to promote rainwater harvesting for households, institutions and communal water-supply systems.

While management of demand is connected with controlling demand and usage patterns, supply is connected with average annual rainfall, intensity of rainfall, type of aquifer, soil, rock, drainage pattern and physiography of the area. Availability of groundwater can be increased by simple interventions, including groundwater recharge through different traditional and contemporary technologies. Recharge can also improve the level of contamination of groundwater—the government report mentions turbidity and high concentrations of chloride, fluoride and iron.[28] According to the report, groundwater is also affected to a great extent by inadequate sanitation facilities. In order to improve this condition, awareness generation and technological knowhow are vital.[29]

According to the Groundwater Survey and Development Agency of Maharashtra, India, while supply-side interventions can increase groundwater recharge by 1.47–2.47 per cent of the total annual groundwater recharge, demand-side management can save 20–33 per cent of groundwater.[30]

Fixing gaps in existing policies

Uganda has no dearth of groundwater reserves. Water stresses that occur locally are due to high population density and crisis of contamination-free groundwater. But the impact of climate change, changing pattern of rainfall and high rates of urbanization may reduce the availability of groundwater in Uganda. This alarming vulnerability calls for immediate policy action from national and local governments.

Among the barrage of threats to human survival—economic crises, terrorism, inequality—perhaps the most urgent—groundwater—is the least prioritized. Fortunately, many policy options can address groundwater depletion. Agencies at the national, district and local levels should cooperate by monitoring the same variables, committing to the same frequency and robustness of data collection, and sharing results even if they generate competitive pressure or embarrassment. Water is a larger public concern than individual political image. This approach is possible with proper incentives from the federal government.

As data provides a more comprehensive view of the groundwater crisis, a reasonable assumption could be that more government policy attention and resources will be devoted to mitigation efforts.

There are several areas for such intervention, including:

- Unplanned and rapidly expanding urban areas contribute to steadily declining groundwater levels. Urban development boundaries can curtail sprawl encroachment on sensitive wetlands and agricultural areas, while permeable pavement and protection and revival of wetlands can increase rainwater absorption and minimize the shock effect of flash floods.
- Scaling up efforts of rainwater harvesting through implementable policy frameworks and additional incentives can significantly improve water availability.
- Existing delivery infrastructure must be improved to manage water that is extracted more efficiently. Good maintenance should be neither politically nor technically complicated.
- Treatment and reuse of wastewater practices and processes must be improved significantly. Much of the groundwater contamination is the product of untreated wastewater discharged into the groundwater. Thus more intensive treatment measures are essential. Additionally, rural Uganda must adopt wastewater reuse programmes more aggressively, including purification systems that enable water to be cycled back for agricultural, industrial and even household use. The latter will depend on public trust of government actions.

These measures in addition to conservation awareness campaign and innovative technologies to recharge the groundwater can arrest groundwater loss and possibly reverse it. They would also boost the quality and supply reliability of rural water, reducing incentives for individuals/communities to install water pumps, which exacerbate groundwater depletion. So far, many local initiatives have not motivated communities due to lack of coordinated guidance. Elevating the groundwater crisis to the national policy agenda is essential, and the federal government must oversee a system that is at once distributed, standardized and robustly monitored and documented. Uganda's social, environmental and economic future will pivot on water.

Institutional mechanism and strategy for planning and implementation at district and national levels

Historically, as social intelligence grew, people realized that human society cannot grow without the bounties of monsoon water extending from the wet months to the dry months. Thus grew the extraordinary tradition of water harvesting. Wells were an important source of irrigation in groundwater-rich regions, but people learnt to harvest groundwater in other ingenious ways too, especially where water in general, and groundwater in particular, were scarce.

The principle of water harvesting is to conserve rainwater—according to local needs and geophysical conditions—where it falls. In the process, groundwater is also recharged.

Traditional water-harvesting systems meet domestic and irrigation needs of people. There is ample evidence to show that community management of traditional systems ensured that basic minimum requirements of all individuals were met.

It is challenging to plan modern systems for villages due to high costs involved. People in rural areas continue to depend to a large extent on traditional systems of water-harvesting structures for both irrigation and drinking water. 'Traditional systems' do not connote old and decrepit structures but they are distinct from large capital-intensive, government-managed structures. Modern systems have, apart from their high monetary costs, enormous ecological costs too. Use of water generated by them usually goes against the basic norms of sound agroclimatic planning. Traditional community-based structures contribute to social cohesion and self-reliance.

The responsibility of taking decisions and action should be left to individuals, groups and local communities working together, encouraging economic independence and optimization of local resources at the micro-level. Traditional systems use low-cost, user-friendly techniques and were easily kept in good operational condition by local communities.[31] Building water-harvesting structures to augment or conserve a groundwater source is a simple task—any contractor with some money can do it. But building an effective structure that launches the process of self-management in village communities is a much more difficult task. Rainwater harvesting demands a new approach to governance itself—a participatory form of governance rather than a top–down bureaucratic one.

The following are the proposed steps for the government to manage traditional water-harvesting structures to conserve and recharge groundwater in Uganda:[32]

1. **Community-based governance**: This should be the starting point for all water and natural resource planning and management. Communities should be the key decision-makers for these water systems. The national policy should be worked out to encourage building of small water-harvesting structures that would depend on and contribute to community governance of natural sources. The communities should be encouraged to continue to play a big role in maintaining traditional water-harvesting structures.

   Communities know that their water-harvesting systems would die if the catchment area deteriorates or the tank bed is encroached upon. If catchment areas of traditional systems are maintained properly and new ones installed wherever feasible, then despite mounting population pressure they can sustain a large part of the people's water needs.

   Local communities, represented by appropriate institutions—village council or village water and sanitation committee (VWSC)—will have absolute right on all rainwater that falls over the common lands of the community, local aquifers, streams and unharvested surpluses from private properties or government lands. This right will be exercised on behalf of all members of the community and with every member treated as an equal partner in all benefits and costs. Costs can be shared according to two principles—that of equal benefits and equal payments or ability to pay. The abiding principle will be decided by the community. Resolution of conflicts and disputes between settlements or communities over the use or misuse of common water resources should take place through institutions of the community instead of the district council. The principles of resolving such issues are best decided by the communities concerned but broadly speaking riparian rights can be one such principle.

2. **Encouraging traditional systems**: Instead of large-scale surface-water systems, community-based institutions associated with traditional water-harvesting systems should be focused on. Traditional water-harvesting uses every drop of rain. Conjunctive management of surface and groundwater should be prioritized where availability of clean water is scarce. In situ water conservation and harvesting systems are technological marvels and have proved to be more reliable and durable than modern systems. They use local material and labour and are planned to suit the micro environment to serve the communities.

   In situ collection of rainwater is desirable as contamination is low in water thus collected. Moreover, expensive transportation costs are eliminated. Long-distance transport of water for community use should be discouraged, especially if it leads to iniquitous distribution of water between different village communities. Habitations should as far as possible be sited keeping water availability in view.

3. **Management of small water-harvesting structures**: The principal role of managing water-harvesting systems should be that of the local community. The role of government agencies has to be minimized. Emphasis should be not on community participation but on community governance. This implies not merely the social management of water-harvesting structures but involvement of the community in both planning and implementation.

   Developing community institutions to construct and manage traditional water-harvesting systems is a difficult task. Wherever possible existing institutions can be used to serve as a nucleus or catalysing agency. But in all likelihood new forms of participatory institutions will have to be evolved. Processes and structures for evolving such organizations and institutional forms should emanate from the grassroots rather than from above but legal support for such institutions will be vital. In evolving appropriate organizational forms for different parts of the country, parameters that should be taken into account include nature of the existing water-harvesting systems, historical traditions in the area, governmental policies and their effects, sociopolitical factors and the water availability–demand relationships in systems.

4. **Water rights**: Communities should be involved in all government plans for water supply to villages. Any changes in the existing traditional technologies should be based on the principles of participatory research and made after the discussion with the communities. Individuals and households should have the right to harvest all the precipitation that falls over their house, property or land, and store it in containers or other systems built, owned and maintained by them. They will, however, not have the right to take water from underground aquifers without the permission of the community/VWSC or from a stream or body of surface water that depends on inflows from catchments beyond the limits of privately owned property. This right will encourage surface-water harvesting. The use of the harvested rainwater, however, shall be such that similar rights of other individuals are not compromised in any way, groundwater recharge is not affected and water sources do not get polluted. Community institutions must have a say in deciding whether a polluting activity can be sited in the catchment areas of traditional systems, regardless of whether this catchment area covers government land or not.

5. **Investments**: Traditional water-harvesting systems cannot be managed in isolation from other systems of community life. Holistic village planning—planning of all village natural resources (land, forests, water and people)—is essential. Investments will have to be made not only in physical structures but also in human resources as desired by communities. Major investments will also need to be made in training people who can interact with the communities. Finances for the initial construction and rehabilitation of the structure should come from the community as much as possible. At least 25 per cent can be obtained from the community, provided the investment planning for rehabilitation is undertaken by the community itself, with district council and other external agencies playing only a supportive role. The exact modalities of financing and cost recovery should be left to the community. The community must contribute effectively at all stages of the project.

   While state subsidies may be necessary, their levels should be decided according to community needs and regional specificities. Further, greater emphasis has to be on subsidies to the community rather than on private subsidies to individuals. District financing becomes relevant where the rural community can barely meet its basic needs. But this investment should be carefully subordinated to and integrated with the interests and decisions of the local communities. Investment planning should have a micro-level focus, preferably a watershed perspective. Every effort must be made to mobilize investment resources from the rural community itself and to the maximum extent possible. Finances should be invested in research and development of all aspects of traditional systems. The conventional cost–benefit analysis does not give any importance to cultural parameters or scarcity values attached by a society to water—this has to change. Methods of project evaluation need to be revised.

6. **National body**: A national body to support and coordinate the building and rejuvenation of traditional water-harvesting structures by local communities is needed. But this body should not be allowed to replace community control over the structures created or regenerated. At best, it will provide broad management principles more as guidelines, and act as an apex body to set government policy, and ensure coordination between various government departments. To enable successful water-harvesting in traditional ways, clear laws to prevent overexploitation of groundwater are necessary. The national body should also fund research on traditional systems to evolve new organizational and institutional mechanisms and help in the development of technologies for upgradation of traditional water-harvesting structures.

7. **New interventions and role of women**: To combine traditional technologies with modern, a wide body of realistic data (on groundwater resources, for example) has to be collected. At present, there is a heavy reliance on thumb rules. Almost no information exists on the linkages between big systems and small ones, both in the past and at present.

   Women play a pivotal role in the operation and maintenance of traditional systems but they do not figure in any research work. As a first step, a comprehensive list of local names and descriptions of different systems throughout the country needs to be prepared.

   Domestic water is not utilized fully and nearly 85–90 per cent of the water is returned as wastewater. With appropriate treatment, this can be used for irrigation, groundwater recharge or even recycled for domestic use. All such possibilities should be explored.

Another important means of optimizing water resources is by promoting the drip and sprinkler irrigation methods.

Technological options to augment groundwater sources

As mentioned in the previous sections, augmentation of groundwater resources ensures clean and sustainable water supply to the villages. There is an urgent need to build small water-harvesting structures following traditional methods.

For effective recharging of groundwater to improve quality and groundwater levels, the following techniques can be applied:

1. Check dams
2. Gabion structures
3. Subsurface dykes
4. Farm ponds
5. Gully plugs
6. Contour bunding
7. Contour trenches
8. Percolation tank
9. Rooftop rainwater harvesting

Table 4: Different technological options for different soils, rock and terrain

Type	About the technology	Soil, rock and/or pre-conditions	Advantage
Check dams	Constructed across small streams with gentle slopes	Can be effective in both hard rock and alluvial formation	• As the structures can impound larger quantities of water, it is helpful in deeper infiltration of water into the ground
Gabion structure	Rock and wire dams constructed across drainage lines in catchment areas	Can be effective in both hard rock and alluvial formation	• Economical as local material can be used • Easy to maintain • Can be constructed on high- to medium-velocity streams • Can withstand medium-intensity flash floods
Subsurface dykes	Underground structures made of soil or cement. They arrest the flow of groundwater out of the sub-basin and thus increase the storage of the aquifer	Can be effective even in undulating hilly terrains	• Impounding subsurface water on the upstream side helps the water, which may otherwise flow away, to percolate into deeper layers of the soil profile • Can withstand high intensity rain/flood
Farm ponds	Dug-out structures with definite shapes and sizes, with proper inlet and outlet structures to collect the surface runoff flowing from the farm area	For storage, underlying soil should be impermeable in soil. A farm pond must be located within a farm drawing the maximum runoff possible in a given rainfall event	• Easy to construct
Gully plugs	Loose boulder structures made on small drainage lines or seasonal streams	Effective in areas with sandstones	• Economical as local material can be used • Easy to maintain • Reduces soil erosion and enhances soil moisture

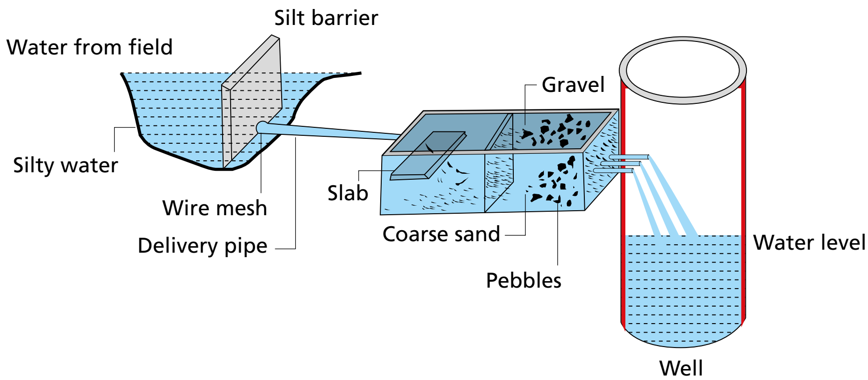
Type	About the technology	Soil, rock and/or pre-conditions	Advantage
Contour bunding	Watershed management practice aimed at building up soil moisture storage involve construction of small embankments or bunds across the slope of the land	Suitable for low rainfall areas (normally less than 800 mm) where gently sloping agricultural lands with very long slope lengths are available and the soils are permeable	• Easy to design and maintain • Enhances soil moisture
Contour trenches	Rainwater harvesting structures, which can be constructed on hill slopes as well as on degraded and barren wastelands. The trenches break the slope at intervals and reduce the velocity of surface runoff. The water retained in the trench will help in conserve the soil moisture and groundwater recharge	Suitable for hilly areas in both low and high rainfall areas	• Easy to design and maintain • Enhances soil moisture
Percolation tank/pond	An artificially created surface waterbody for surface run-off to percolate and recharge groundwater storage. The percolation tank should have adequate catchment area	Effective in areas where soil is permeable. Can also be effective in hard rock areas that are highly fractured and weathered	• Economical • Easy to maintain • Existing village tanks which are normally silted and damaged can be modified to percolation tanks
Dug well recharge	Dug wells in rural areas that have gone dry can be used as structures to recharge groundwater. Storm water, tank water, canal water, etc. can be diverted into these structures to directly recharge dried aquifers. This will guide the recharge water through a pipe to the bottom of well, below the water level to avoid scoring of bottom and entrapment of air bubbles in the aquifer. In rural areas rainwater runoff can be channelized and recharged to dug wells through a filter.	Can be effective in both hard rock and alluvial formations	• Economical structure
Recharge shaft	An artificial recharge structure that penetrates the overlying impervious horizon and provides effective access of surface water for recharging the phreatic aquifer	Suited for areas with deep groundwater levels	• Requires only small land area • No loss of water through evaporation • Economic and can be designed by locals • Rate of recharge is high and impact can be observed quickly
Rooftop rainwater harvesting	Rooftop rainwater can be conserved and used for recharge of groundwater. This approach requires connecting outlet pipes from rooftops to divert water to either existing wells/ tube wells/ bore well or specially designed wells.	Both hard rock and soft rock areas	• Can be implemented on local plots

Source: Compiled by CSE

Check dam built across a stream.

Source: CSE

Figure 2: Dug well recharge

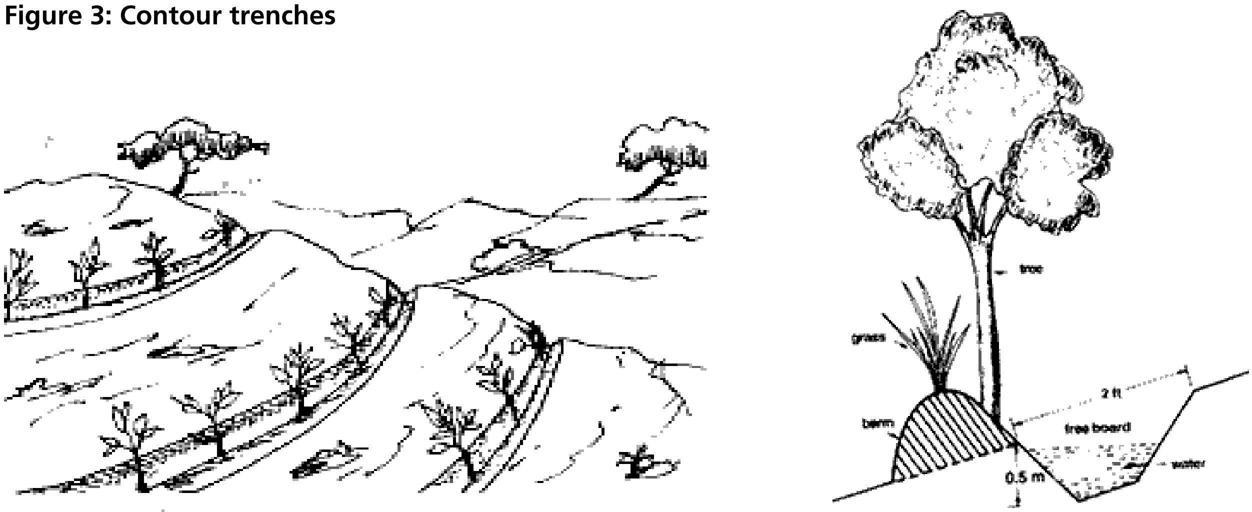


Source: http://cgwbchd.nic.in/ar10.htm

Farm ponds store rainwater and supply water through the year.

Source: CSE

Figure 3: Contour trenches

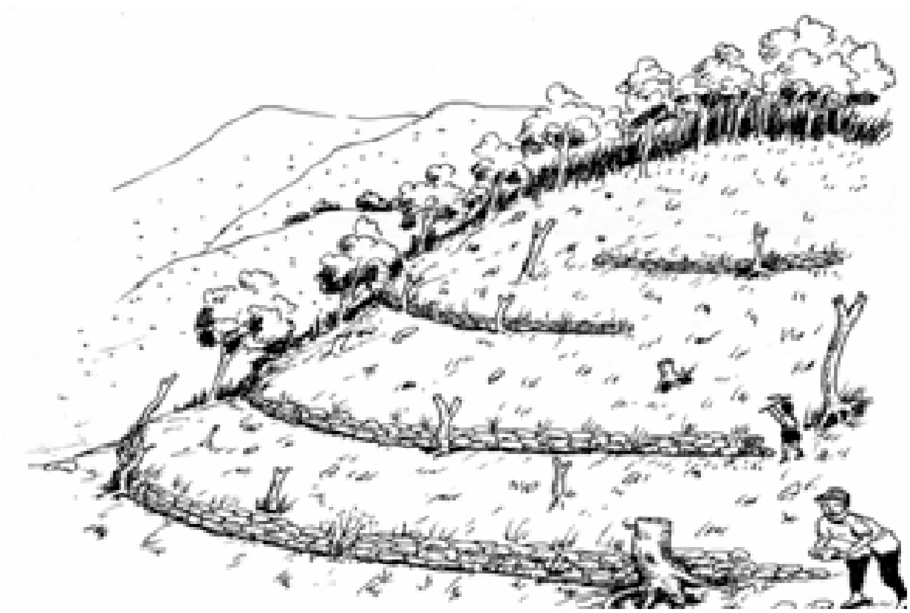


Source: https://www.indiawaterportal.org/articles/techniques-slow-runoff-and-erosion-steeply-sloping-land

Rooftop rainwater harvesting helps sustain drinking and cooking requirements throughout the year in Northeast India.

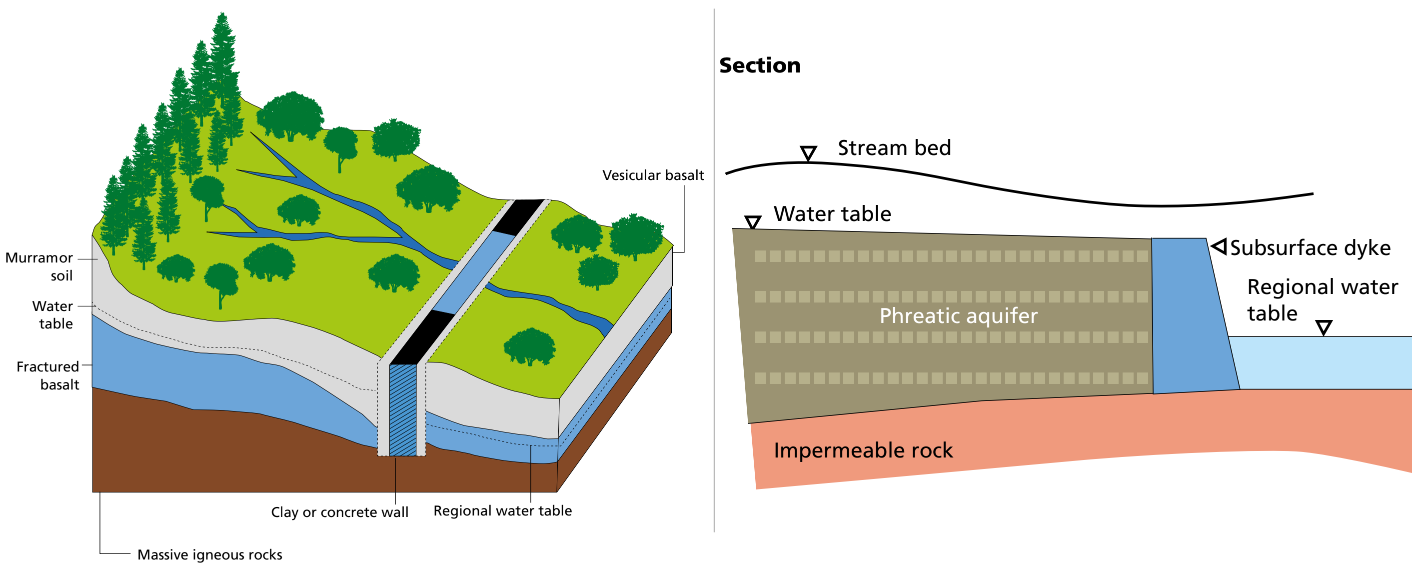
Source: CSE

Figure 4: Contour bunding



Source: Aryal, K.P. et al., 2014. How Can Research and Development Help Upland Farmers Improve their Farming Systems? Experiences in Participatory Technology Development. Sustainable Sloping Lands and Watershed Management Conference.

Figure 5: Subsurface dyke



Source: http://cgwbchd.nic.in/ar11.htm

Monitoring and evaluation

Inadequate participation of the community in planning, implementation and monitoring of the groundwater-based water supply in rural areas are the main impediments to sustainability of the source.

Safe drinking water sourced from groundwater should be free from any bacteriological and chemical contamination. Bacteriological contamination may cause diarrhoea, dysentery, typhoid fever, cholera, jaundice, etc. Flouride in drinking water many cause dental, skeletal and non-skeletal fluorosis. Arsenic contamination of drinking water causes dermatosis and excess nitrate may result in blue baby syndrome in newborn babies.

There is a need for water quality and surveillance programmes to monitor the quality and quantity of groundwater sources. A community-based management system is essential for this. The village council and the VWSC should be made responsible for implementing the programme to supply regular clean water for the village. There is a need to develop capacities of the members of VWSC, community leaders, primary teachers, health workers etc. for effective implementation of this programme.

The two main key steps for implementing such programmes are as follows:

1. Assessment of water quantity and quality
2. Preventive measures

1. Assessment of water quantity and quality

The first part of implementation is measuring the groundwater level. This needs to be done every month to record any rise or decline in the level of groundwater. Generally, water level measurements are carried out from dug wells or from purpose-built piezometres (observation bore wells or tube wells).

Groundwater levels should be monitored to:

a. Have an overview about the groundwater regime. Monitoring gives a good idea about water scarcity, water logging and changes in water level.
b. Understand natural recharge or withdrawal and seasonal fluctuations.
c. Demarcate the area falling under the stress of groundwater extraction
d. Map areas where groundwater augmentation is required/possible through artificial methods.[33]

Piezometers may be used to accurately measure groundwater levels. Their location should be decided in communication with the community and Village Water Sanitation Committee (VWSC). Members of the village council and VWSC should be trained to record the readings. In remote and/or rocky areas, however, where geographic or economic conditions make it difficult to implement piezometers, recording the level of the groundwater in open dug wells is economical. To make the system economical or for easy handling, sensor-based cables can also be immersed in borewells/tube wells to get a reading of groundwater level. It is essential to know about the type and condition of groundwater abstraction structures from which the water level will be recorded.

The following are important criteria to fix a well as an observation well (also referred to as recording station):

a) The well should be in use and have regular withdrawal; and
b) It must be representative for the general geomorphic set up prevailing in the area.

The database generated through regime monitoring forms the basis for planning the groundwater development and management programme. Not just the quantity but the quality of the groundwater must be analysed.

The groundwater samples, collected every fortnight, have to be checked for contamination. It is important to identify the source of contamination and likely solutions. Contamination sources should be surveyed on a regular basis (biweekly) wherever groundwater is the source of drinking water. The survey is expected to pinpoint possible reasons for contamination of sources. Once the reasons are known, solutions can be accordingly be devised and adopted.

The following points need to be considered and observed during the sanitary survey:

- Cleanliness around the source and in the catchment;
- Accumulated water around the source;
- Likely causes of pollution of percolation tanks and/or village tanks etc. on the upstream side;
- Presence of nearby toilets.

Field testing kits can be used at the local level. Trained technicians should test pH, alkalinity, hardness, chloride, total dissolved salts (TDS), fluoride, nitrate, nitrite, phosphate, turbidity and residual chlorine through field testing kits. The H_2S strip test should be performed to detect indication of bacteriological contamination. The village council and VWSC should see that they have trained technicians to perform such field tests. They should also ensure that they have collection bottles as per laboratory guidelines and proper filed testing kits. If the communities note any contamination, it has to be reported to the District Council.

2. Preventive measures

To prevent contamination of the groundwater sources, villages should be open-defecation free, and solid and liquid waste should be safely disposed of or reused. Industrial effluents should not seep into the soil and communities should be made aware of the ill effects of high doses of chemical fertilizers and pesticides.

The following preventive measures should be taken to protect groundwater from anthropogenic contamination:[34]

- Area around the groundwater abstraction should be kept clean;
- The catchment around the groundwater should be protected so that clean runoff can recharge the groundwater;
- Wastewater (black and grey water) should not seep into the soil or groundwater. Toilets should be installed with the appropriate technology to treat black and grey water from bathrooms and kitchens before further disposal;
- Washing clothes and utensils around the abstraction point should be banned;
- Toilets and soak pits should be at least 15–20 metres from the source of groundwater;
- Cattle farms should also not be allowed within a radius of 15 m of the groundwater source;
- Percolation tanks near the groundwater source or upstream of the source should be protected;
- Growth of bushes and algae should be prevented in the vicinity of the groundwater source; and
- The source should be fenced off so that the area in the vicinity of the groundwater can be well protected.

Data evaluation: This involves processing large amounts of data generated in the course of monitoring the groundwater quality and quantity. This information can be utilized for decision-making and for improving the O&M component of the surveillance programme. Reports based on evaluated data should be presented to the village council/VWSC for further inputs that can be incorporated into the planning.

Information, education, communication

While preparing the information, education and communication (IEC) for awareness on conservation of groundwater sources in the village, a comprehensive evidence-based strategy has to be developed so that it can be easily adopted by policymakers and implementers of the strategy.

Communication strategies aim to change the behaviour of household owners, members of village water and sanitation committees or /village council.

They should seek to:[35]

- Create awareness on efficient use of groundwater;
- Promote safe disposal of black and grey water to stop contamination of soil and groundwater;
- Create awareness on maintenance of quality and quantity of groundwater;
- Create awareness for urgent need for mutual cooperation and adopting integrated planning and participatory approach in the management of groundwater;
- Create awareness among the people about the necessity of water conservation;
- Promote documenting and disseminating of knowledge of groundwater science and technology as well as issues concerning sustained development of the water resources;
- Create awareness about necessity of adopting measures for rainwater harvesting and artificial recharge of groundwater to meet present and future water needs; and
- Strengthen awareness infrastructure, especially campaign mechanism and support structure.

To reach these objectives, the following activities are suggested:

A. *For village councils/VWSCs:*

- Factsheet, FAQs, multimedia presentations;
- Meetings in local language;
- Workshops, conference and/or seminars to spread the knowledge on technologies, financial options; and
- Communications by celebrities and ministers to sensitize the population about the benefits of water conservation.

B. *For households and communities*

- Fairs and exhibitions;
- Talk shows on radio and television; jingles; including the subject of groundwater management in serials and radio shows; and
- Painting competitions for school children.

C. *For media*

- Meetings with journalists and editors to make them aware about groundwater management and conservation.
- Exposure to success stories and fellowships offered to cover stories on the subject.

D. *For corporates*

- Meetings and special events to raise awareness on water conservation through rainwater harvesting and groundwater recharge, especially among corporates interested in funding safe sanitation.

E. *Masons and plumbers*

- Factsheet, FAQs, multimedia presentations on water conservation through rainwater harvesting and groundwater recharge;
- Meetings in the local language; and
- Workshops on technologies.

The output of such strategies will be as follows:

- Reduction in contamination of water and soil;
- Reduction in expenditure on health-related issues;
- Every household starts using 'sanitary toilets' following design specifications;
- Faulty toilets are retrofitted;
- Household owners voluntarily make soak pits for groundwater recharge;
- The communities start using water judiciously;
- Rooftop rainwater harvesting is seen in all the households;
- Communities stop washing clothes and utensils near groundwater abstraction structures;
- Farmers use water-efficient irrigation systems;
- Village council/Village Water and Sanitation Committee (VWSC) make construction of groundwater-recharge structures a priority in the annual implementation plan;
- VWSC/village council monitor the groundwater levels and quality at a regular basis;
- VWSC members are well trained to monitor and document groundwater level and quality;
- Village council/VWSC maintain not only the groundwater structures but also catchments;
- Well-trained masons and plumbers are available in the villages to construct technologically appropriate groundwater structures.

6. Conclusion and recommendations

Groundwater—supplied through protected springs, borewells and shallow wells—constitutes over 90 per cent of the water supply for rural areas in Uganda. The reserve is no doubt currently quite sufficient except in semi-arid and arid regions in the country.

Unplanned urbanization, loss of waterbodies and variability of temporal and spatial rainfall will, however, soon impact the natural recharge of the groundwater. Additionally, Uganda also faces the problem of contaminated groundwater due to poor management of faecal sludge and natural mineralization.

The country should thus plan for groundwater recharge policies and strategies to make groundwater reserves sustainable and safe. Bacteriological contamination can be removed by strategizing the management of faecal sludge.

The government of Uganda has always promoted rainwater harvesting through storage of rainwater. But the country needs to focus on groundwater recharge as natural recharge is declining. There has been a decline in lakes and wetlands—the large recharge bodies in the country—due to encroachment. This impacts groundwater reserves. The country now needs to gear up to implement policies and strategies with regard to groundwater and catchment protection with a help of a mix of technological solutions and capacity-building and behaviour-change strategies planned carefully for different levels of stakeholders.

Task 1: Strengthen policies and strategies on water conservation: Although there are several policies and strategies on groundwater, we recommend the following to strengthen the policies and strategies:

1. Instead on supply-side management, the country should focus on demand-side management;
2. Protection of wetlands and waterbodies to recharge groundwater efficiently and protect the areas from flash floods should be strategized;
3. Policies on reuse of wastewater should be in place;
4. Policies on safe management of faecal sludge should be introduced to protect the groundwater from bacteriological contamination; and
5. Village council should be incentivized for water conservation.

Task 2: Create manual and menu on rainwater harvesting/groundwater recharge technologies: Uganda has diverse hydrological conditions, varying from shallow groundwater (0–12 metres below the ground) to deep groundwater (30–66 metres below the ground) levels. We recommend the following:

1. Creation of database on technological interventions for groundwater recharge;
2. Promotion of small water-harvesting structures;
3. Reviving and renovating traditional water-harvesting structures; and
4. Surveillance of groundwater should be part of all the projects.

Task 3: Improve the institutional mechanism for the implementation of the policies on groundwater recharge: For the better implementation of the policies on groundwater recharge, we recommend the following:

1. Communities (especially women) should be the key decision makers for all the government plans on rural water supply, from planning to implementation;
2. Capacity-building and awareness programmes should be planned for users, artisans, NGOs, CSOs and government authorities involved in the water supply sector; and
3. A national body to support and coordinate the building and rejuvenation of traditional water-harvesting structures by local communities is needed.

The Centre for Science and Environment (CSE), New Delhi, India, will work closely with the Ministry of Water and Environment, Uganda. CSE will help the Ministry of Water and Environment to plan policy/strategies for augmenting groundwater reserve through rainwater harvesting.

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More than 75 per cent of Uganda's population lives in rural areas and depends heavily on groundwater resources. While groundwater reserves are currently adequate to cater to the needs of the rural population—except in a few dry patches in the northeast and southwest—temporal and annual variations of rainfall, unplanned urbanization and encroachment of waterbodies have reduced the natural recharge of the groundwater. Over and above this, groundwater also faces contamination due to natural and anthropogenic reasons.

Uganda receives 66,000 million cubic metres water from rainwater and other inflows. The country should use its high rainwater harvesting potential to augment its groundwater resources. It has promoted rainwater harvesting through storage of rainwater in tanks, but the country also needs to explore community-centric technological options for groundwater recharge. Strengthening of strategies and policies on water conservation, including rainwater harvesting, is the need of the hour.

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