

# Natural renewable water resources and ecosystems

## Abstract

A booming economy, high population, land-locked location, vast area, remote separated and poorly accessible rural areas, large reserves of oil, excellent sunshine, large mining sector and cattle farming on a large scale, are factors which are most influential to the total water scene in Sudan. It is expected that the pace of implementation of water infrastructure will increase and the quality of work will improve in addition to building the capacity of the private and district staff in contracting procedures. The financial accountability is also easier and more transparent. The communities should be fully utilised in any attempts to promote the local management of water supply and sanitation systems. There is little notion of 'service, invoice and move on'. As a result, there are major problems looming with sustainability of completed projects. A change in water and sanitation sector approaches from supply-driven approach to demand-responsive approach call for full community participation. The community should be defined in terms of their primary role as user/clients. Private-sector services are necessary because there are gaps, which exist as a result of the Government not being able to provide water services due to limited financial resources and increase in population. The factors affecting the eco-environmental changes are complex, interrelated, and interactive. The deterioration problems of water and sanitation have attracted some attention in recent years. There is an urgent need to study possible rehabilitation measures to ensure a sustainable and excellent water quality and improved sanitation.

**Keywords:** Sudan, water technology, sustainable development, environment, mitigation measurements

Volume 2 Issue 6 - 2017

**Abdeen Mustafa Omer**

Energy Research Institute, Forest Road West, UK

**Correspondence:** Abdeen Mustafa Omer, Energy Research Institute, 17 Juniper Court, Forest Road West, Nottingham NG7 4EU, Nottinghamshire, UK, Email [abdeenomer@yahoo.co.uk](mailto:abdeenomer@yahoo.co.uk)

**Received:** May 22, 2017 | **Published:** October 16, 2017

## Introduction

Globally, buildings are responsible for approximately 40% of the total world annual energy consumption. Most of this energy is for the provision of lighting, heating, cooling, and air conditioning. Increasing awareness of the environmental impact of CO<sub>2</sub> and NO<sub>x</sub> emissions and CFCs triggered a renewed interest in environmentally friendly cooling, and heating technologies. Under the 1997 Montreal Protocol, governments agreed to phase out chemicals used as refrigerants that have the potential to destroy stratospheric ozone. It was therefore considered desirable to reduce energy consumption and decrease the rate of depletion of world energy reserves and pollution of the environment. This chapter discusses a comprehensive review of energy sources, environment and sustainable development. This includes all the renewable energy technologies, energy efficiency systems, energy conservation scenarios, energy savings and other mitigation measures necessary to reduce climate change.

Absolute sustainability of water supply is a simple concept: no depletion of world resources and no ongoing accumulation of residues. Relative sustainability is a useful concept in comparing the sustainability of two or more generation technologies. Therefore, only renewables are absolutely sustainable, and nuclear is more sustainable than fossil. However, any discussion about sustainability must not neglect the ability or otherwise of the new technologies to support the satisfactory operation of the electricity supply infrastructure. The electricity supply system has been developed to have a high degree of resilience against the loss of transmission circuits and major generators, as well as unusually large and rapid load changes. It is unlikely that consumers would tolerate any reduction in the quality of the service, even if this were the result of the adoption of otherwise benign generation technologies. Renewables are generally weather-dependent and as such their likely output can be predicted but not controlled. The only control possible is to reduce the output below

that available from the resource at any given time. Therefore, to safeguard system stability and security, renewables must be used in conjunction with other, controllable, generation and with large-scale energy storage. There is a substantial cost associated with this provision. Water resources plans are developed to guide future decisions and are to be developed for each river basin and state, as well as the country. The objective is to coordinate efforts and establish guidelines and priorities for water allocation and water pricing. The priorities established for water allocation will be used in critical drought conditions. Water pricing is the single most controversial instrument of the law. The pricing system is also the most difficult step to implement. The pricing system recognises the economic value of water, as stated in the principles of the policy. The development of a new, modern, and complete water resources information system is one of the basic needs for the implementation of the water resources management system. The decision process in drought or flood conditions, and also in overexploitation cases, can only be correct if based on a reliable information system. A complete and comprehensive database on water availability, users, water quality monitoring, current technologies (like geographical information systems), is certainly the way to produce an efficient framework for decision-making. Lack of information is one of the most critical points regarding the development and implementation of the new management system. The institutional framework provides the basis by which all actions are taken, and an assessment of its functional character helps determine the collaborative potential.

## Water and sustainable development

The limited water resources and increased demands to cope with the rapid development, it is paramount to inaugurate strategies that control this valuable resource through augmentation and conservation measures. Such measures essentially include rationalisation of water use, minimising losses, quality protection, exploration, artificial

recharge and water harvesting techniques. A schematic technological advancement of low cost water supply systems such as dug wells, roof top catchments, hafirs and small dams combined with development of guidelines for settlement policy will hopefully lead to an improvement of water supply systems, water quality and reduction of the distance to the supply points. In the past decade, sustainability has increasingly become a key concept and ultimate global for socio-economic development in the modern world. Without a doubt, the sustainable development and management of natural resources fundamentally control the survival and welfare of human society. Water is an indispensable component and resource for life and essentially all human activities rely on water in a direct or in indirect way. Yet supplying water of sufficient quantity and safe quality has seldom been an easy task. Although sustainability is still a loosely defined and evolving concept, researchers and policy-makers have made tremendous efforts to develop a working paradigm and measurement system for applying this concept in the exploitation, utilisation and management of various natural resources. In water resources arena, recent development has been synthesised and presented in two important documents published by ASCE<sup>1</sup> and UNESCO,<sup>2</sup> which attempt to give a specific definition and a set of criteria for sustainable water resource systems. When considering the long-term future as well as the present, sustainability is concept and goal that can only be specified and implemented over a range of spatial scales, of which urban water supply is a local problem with great reliance on the characteristics and availability of regional water resources.

## Water resources

Water is one of the most fundamental of natural resources that a country must harness in its efforts for rapid economic development. The role of water in the development process cannot be over-emphasised. Sudan is rich in water (from the Nile system, rainfall and groundwater) and lands resources. Surface water resources are estimated at 84 billion m<sup>3</sup>. The annual rainfall varies from almost nil in the arid hot north to more than 1600 mm in the tropical zone of the south. The total quantity of renewable groundwater is estimated to be 260 billion m<sup>3</sup>, but only 1% of this amount is being utilised. Internal renewable water resources (IRWR) include the average annual flow of rivers and the recharge of groundwater (aquifers) generated from endogenous precipitation-precipitation occurring within a country's borders. IRWR are measured in cubic kilometres per year (km<sup>3</sup>/year). Since data were collected in different years, they may not be directly comparable.

## Uses of water

The utilisation of water in Sudan is widely estimated in agriculture, human use, domestic, animal uses, industrial, hydropower generation and navigation. The agricultural sector is the major source of water consumption in Sudan. Sudan is presently utilising 16.5 x 10<sup>9</sup>m<sup>3</sup> annually from its share in irrigated agriculture sub-sector, currently covering an area of 1.7 x 10<sup>6</sup> hectares. The potential is three-fold. The irrigated crops include: cotton, wheat, sorghum, groundnuts, sugarcane, vegetables and fruits. Mechanised and traditional rain-fed farming sectors cover an area estimated annually at about 8-10 x 10<sup>6</sup> hectares. The total area cropped in the rain-fed areas varies from year to year depending on rainfall. Crops grown in the rainfall sub-sector include: sorghum, millet, sesame, sunflower, and groundnuts. The potential in the rainfall sector is more than fivefold. The southern tropical zone of Sudan is distinct with red lateritic soil and heavy rainfall ranging between 1000-1500 mm over 7-8 months. Agriculture is largely subsistence with a wide range of food crops including:

maize, sorghum, millet, root crops, banana, pulses, tea, and coffee. Because of the marked fluctuation between the flood discharge and the low season period in the Nile system, storage reservoirs in Sennar, Rosaries, Griba and Jebel Awlia were constructed to ensure the availability for water during the recession period. These dams are used for irrigation, navigation and hydropower generation. Drinking water supplies have been provided for people and animal in most of the urban and rural areas, but still more than 40% of the rural areas, and more than 25% in urban areas are in need of safe drinking water supplies. Water use for industry and sanitation is still very limited. The demand for water in industries at the present estimated at about 0.24 x 10<sup>9</sup> m<sup>3</sup> per year, and most of which from the surface water.

The most important research and development policies which have been adopted in different fields of water resources are:

1. The water resource;
2. Irrigation development;
3. The re-use of drainage water and groundwater;
4. Preventive maintenance of existing facilities, including canals;
5. Aquatic weed control and river channel development, and
6. Protection plans for water resources in general. The base of physical and human resources can provide for sustainable agriculture growth and food security for itself and for others in the region.

Failure to plan for sustainability in the past derives from several causes and constraints, which are manageable. These include misguided policies, poor infrastructure, low level of technology use, recurring droughts and political instability. Perhaps the biggest challenge is that of finding resources for capital improvements in the light of changing water-quality regulations and ageing systems.<sup>3</sup> Environment institutions and regulators are already working to solve the next set of issues in their constant pursuit of better quality of live. Increasing watershed and source protection that combat microbial and organic contaminations is possible with new detection techniques that enable identification, and control of pesticide runoff, and reduce chlorine by-products. Upgrades of ageing infrastructure are receiving unprecedented attention. Surface-water systems are continuing to rely on conventional treatment (coagulation, flocculation, sedimentation, filtration and disinfection) for particulate removal, but other treatment processes such as ozone and granular activated carbon will see increased use, while new disinfection strategies will be needed to minimise both microbial risks and unwanted by-products. Sudan is, therefore, moving into a new era in the protection of drinking-water supplies. It is now time for water utilities to combine creative management, dependable treatment methods and new technologies to ensure that drinking water is as safe as possible. The demand for water in Sudan has increased tremendously over the years and will continue to increase in view of the accelerating pace of population growth, urbanisation and industrialisation. There are many approaches and programs through which human resource can be properly developed for the water sector.

These programs are not mutually exclusive and include:

- a. Non-formal education through media and non-governmental groups.
- b. Formal education through universities and technical colleges.
- c. On-the-job training and regular refresher courses.

## Water management

The semi-autonomous Sudan Gezira Board (SGB) manages the Gezira Scheme on a vertically integrated basis. The MIWR is responsible for managing the Sennar Dam on the Blue Nile and the upper reaches of the irrigation system, responding to requests for water delivery from SGB's field staff. Within the scheme, the SGB serves as landlord, operates and maintains the lower reaches of the irrigation system and provides most of the inputs and services required by farmers to produce cotton, which is transported by the Board to its ginneries and sold on behalf of growers by the Sudan Cotton Company Limited. The SGB recovers the cost of advances made for inputs and services from the cotton sales before payment is made to the farmer. Tenants are wholly responsible for growing other crops in prescribed rotations with cotton (sorghum, groundnuts, forage, wheat, and vegetables), making their own arrangements for input supplies and marketing. By 2001 in the Gezira Scheme, Minor Canal Committees had been formed along the minor irrigation canals and representatives of each of these committees constitute the Irrigation Committee at the block level. In addition to the Irrigation Committee, a Financial Committee has been established that is coordinating the reimbursement of the seasonal credits and arrangements for procurement of new inputs. The Irrigation Committee with representatives of each of the minor canal committees will be responsible for the operation and maintenance of the minor irrigation system, a task presently entrusted to the SGB, with the Ministry of Irrigation responsible of supplying the main system.

To address some of the problems facing irrigation management and development the Government has formalized a policy framework that includes:

- I. Transferring the operation and production of large- and medium-size irrigation schemes to the farmers and giving them full responsibility for water management on the irrigation system below the minor canals level through establishment of voluntary water users associations (WUAs).
- II. Fostering sustainable productivity of the large schemes through rehabilitation, combined with financial and institutional reform.
- III. Grouping, rehabilitating and handing over the relatively small size pump schemes in the Blue Nile and the White Nile. These schemes were originally established and run by the government. Recently, and in accordance with the economic reforms, these schemes were handed over to the private sector represented by individual farmers, cooperatives or private companies.

### The policy regime in water quality management

Apart from effluent regulations, and sometimes, national water quality guidelines, a common observation are that few developing countries (Sudan is no exception). Although water supply is seen as a national issue, pollution is mainly felt at, and dealt with, at the local level. With few exceptions, national governments in developing countries have little information on the relative importance of various types of pollution (agriculture, municipal, industrial, animal husbandry, aquaculture), and therefore, have no notion of which is of greatest economic or public health significance.<sup>4</sup> Usually freshwater quality management is completely divorced from coastal management even though they are intimately linked. Consequently, it is difficult to develop a holistic management plan for assuring water quality or to efficiently focus domestic and donor funds on priority issues.

A Sudanese national water policy should include the following water quality components:

- I. A policy framework that provides broad strategic and political directions for future water quality management.
- II. A strategic action plan for water quality management based on priorities that reflect an understanding of economic and social costs of impaired water.

This plan should include the following components:

1. A mechanism for identifying national priorities for water quality that will guide domestic and donor investment.
2. A plan for developing a focused and cost-effective data programme for water quality and related uses, as a basis for economic and social planning.
3. A consideration of options for financial sustainability including donor support, public-private sector partnerships, and regional self-support initiatives.
4. A regulatory framework that includes a combination of appropriate water quality objectives (appropriate to that country and not necessarily based on Western standards) and effluent controls. This must include both surface and groundwater.
5. A mechanism for public input into goals and priorities.
6. A process for appointing specific agencies with responsibility for implementation so that accountability is firmly established and inter-agency competition is eliminated.
7. Specific mechanisms for monitoring the quantity of drinking water, at the community level if necessary.

National data standards that must realistically reflect national needs and capabilities. The objective is to ensure reliable data from those organisations that provide information for national water management and for community- level drinking water quality.

### Perspectives for agricultural water management

The country has an agricultural potential of 105 million ha, of which only 16.7 million ha are cultivated and only about 1.9 million ha out of an irrigation potential of 2.8 million ha are under irrigation now.<sup>5-7</sup> Therefore, there is ample room for further developments especially in the irrigation sub-sector.

However, there are three major constraints to irrigation development in Sudan:

1. The ineffective process of annual maintenance of civil works (reportedly due to lack of funds), especially for the removal of silt and weeds from irrigation canals, which slows down water flow and causes continuous shrinkage of the actual irrigated area;
2. The steady increase in development costs, which has been aggravated by the continuous devaluation of the local currency;
3. The lack of farmer involvement in the planning and operation of the schemes and related services.

Generally, the water supply for all of the irrigation schemes is provided by dams and/or pumps and extensive networks of canals covering the whole schemes as well as drainage networks of canals. The overall objective of water management policies is to improve water use efficiency in agriculture, which includes efficient control of water in the irrigation networks, maintenance of the irrigation structures, provision of technical capacities capable to operate the systems, and efficient and economical maintenance of the irrigation systems. Supplementary irrigation could increase the very low

or zero productivity of crops and fodder. The conjunctive use of groundwater and surface water could help to optimize the water resource productivity. Sudan is rich in water (from the Nile system, rainfall and groundwater) and lands resources (Tables 1-4). Surface water resources are estimated at 84 billion m<sup>3</sup> and the annual rainfall varies from almost nil in the arid hot north to more than 1600mm in the tropical zone of the south. The total quantity of groundwater is estimated to be 260 billion m<sup>3</sup>, but only 1% of this amount is being utilised. Water-resources assessment in Sudan is not an easy task because of uncertainty of parameters, numerous degrees of freedom of variables, lack of information and inaccurate measurements.

**Table 1** Land use (millions of ha)

Land use	Millions
Geographical area (Total Sudan area)	250.6
Land area	237.6
Cultivable area	8.4
Pastures	29.9
Forests and woodland	108.3
Uncultivable land	81
Area under crop (irrigated, rain-fed, mechanized, and rain-fed traditional)	10

**Table 2** Land-resource zones

Zone	Area as % to total area of Sudan	Persons Per km <sup>2</sup>	Mean average rainfall range (mm)
Desert	44	2	0-200
QOS sands	10	11	200-800
Central clay plains	14	19	200-800
Southern clay plains	12	8	800-900
Ironstone plateau	12	7	800-1400
Hill area and others	8	16	Variable

**Table 4** Geological formations

Basins	Amount of Water Recharged (106 m <sup>3</sup> )	Water Level Below Land (m)	Aquifer Thickness (m)	Velocity (m/Year)	Abstraction (106 m <sup>3</sup> /Year)
Sahara Nile	136	30-100	300-500	1-2.5	7.3
Sahara Nubian	20.6	Oct-50	300-500	0.8-1.5	1.5
Central Darfur	47.6	25-100	250-550	0.3-6.0	5.5
Nuhui	15.4	75-120	200-400	1.0-2.75	1.6
Sag El Na'am	13.5	50-1000	300-500	1.0-25.0	2.5
River Atbara	150	100-150	250-300	0.3-5.0	2.3
Sudd	341	25-Oct	200-400	0.1-1.8	1.8
Western Kordofan	15	50-70	300-500	0.1-0.3	1.7
Baggara	155	Oct-75	300-500	0.1-2.4	11.9
Blue Nile	70.9	Oct-50	250-500	0.1-2.5	10.2
The Alluvial	N.A	Shallow	N.A	N.A	N.A
Gedaref	41.7	50-75	200-500	0.1-2.0	1.2
Shagara	1.1	25-30	200-300	0.1-2.5	0.7

A national water-quality-policy should include the following water quality components:

- I. A policy framework that provides broad strategic and political directions for future water-quality management.
- II. A strategic action plan for water-quality management based on priorities that reflect an understanding of economic and social costs of impaired water.

**Table 3** Water resources

Water resource	Available number	Static water level (m)	Number
Haffirs	824	0-0	824
Slow sand filters	128	0-0	128
Open shallow wells	3000	0-10	3000
Boreholes deep wells	2259	0-25	1248
-	-	26-50	478
-	-	51-75	287
-	-	76-100	246

However, according to seasonal water availability, Sudan could be globally divided into three zones:

- a. Areas with water availability throughout the year are the rainy regions (equatorial tropical zones);
- b. Areas with seasonal water availability; and
- c. Areas with water deficit throughout the year, which occupy more than half the area of Sudan.

Apart from effluent regulations, and sometimes, national water quality guidelines, a common observation is that few developing countries (Sudan is not an exception) include a water-quality-policy context. Whereas water supply is seen as a national issue, pollution is mainly felt at, and dealt with at, the local level. With few exceptions, national governments have little information on the relative importance of various types of pollution (agriculture, municipal, industrial, animal husbandry, and aquaculture), and therefore, have no notion of which is of greatest economic or public health significance. Usually freshwater quality management is completely divorced from coastal management even through these are intimately linked. Consequently, it is difficult to develop a strategic water quality management plan or to efficiently focus domestic and donor funds on priority issues.<sup>7-9</sup>

This plan should include the following components:

1. A mechanism for identifying national priorities for water-quality management that will guide domestic and donor investment.
2. A plan for developing a focused and cost-effective data programme for water quality and related uses, as a basis for economic and social planning.

3. A consideration of options for financial sustainability including donor support, public-private sector partnerships, regional self-support initiatives.
4. A regulatory framework that includes a combination of appropriate water-quality objectives (appropriate to that country and not necessarily based on Western standards) and effluent controls. This includes both surface and groundwater.
5. A methodology for public input into goals and priorities.
6. A process for tasking specific agencies with implementation so that accountability is firmly established and inter-agency competition is eliminated.
7. Specific mechanisms for providing drinking water monitoring capabilities, at the community level if necessary.
8. National data standards that must realistically reflect national needs and capabilities. Nevertheless, the objective is to ensure reliable data from those organizations that provide information for national water management purposes and at the community level for drinking water monitoring.

## Conclusion

Water resources plans are developed to guide future decisions and are to be developed for each river basin and state, as well as for the country. The overall objective is to coordinate efforts and establish guidelines and priorities for water allocation and water pricing. The priorities established for water allocation would be used in critical drought conditions. The water quality classification of water bodies by different classes of use is the basis for truly integrating the quality and quality of water management. Water pricing is the single most controversial instrument of the law. The pricing system recognizes the economic value of water, as stated in the principles of the policy, but is also the most difficult step to implement. It is expected that the pace of implementation will increase and the quality of work will improve in addition to building the capacity of the private and district staff in contracting procedures. The financial accountability is also easier and more transparent. The factors affecting the eco-environmental changes are complex. There are interrelated and interact. The

deterioration problems of water and sanitation have attracted some attention in recent years. There is an urgent need to study possible rehabilitation measures to ensure a sustainable and excellent water quality and improved sanitation.

## Acknowledgments

None.

## Conflicts of interest

The authors declare there is no conflict of interests.

## Funding

None.

## References

1. ASCE Task Committee on sustainability criteria. Sustainability criteria for water resource systems. Reston, Virginia, USA; 1998.
2. UNESCO Working Group MIV. Sustainability criteria for water resource systems. UK: Cambridge University Press; 1999.
3. James W. Managing water as economic resources. Overseas Development Institute (ODI), UK; 1994.
4. Salih AMA, Ali AAG. Water scarcity and sustainable development. *Nature and Resources*. 1992;28(1).
5. Omer AM. Water and environment in Sudan: the challenges of the new millennium. *NETWAS*. 2000;7(2):1–3.
6. Omer AM. Sustainability criteria for water resource systems: Sustainable development. *Technologies for Renewable Energy and Water Conservation*. 2016;5(2).
7. Sheu H, Hong T. Performance evaluation model for project managers using managerial practices. *Project Management*. 2008;25(6):543–551.
8. Skinner KS, Bruce-Burgess L. Strategic project level river restoration protocols- key components for meeting the requirements of the water framework directive. *J Chartered Institute Water Environmental Management*. 2005;19(2):135–142.
9. EPA. Inventory of USA GHG emissions and sinks: 1990–2007. Review of world water resources by country, FAO, Rome; 2011.