FINAL REPORT

ASSESSMENT OF GROUNDWATER AVAILABILITY AND ITS CURRENT AND POTENTIAL USE AND IMPACTS IN TANZANIA

Report Prepared for the
International Water Management Institute (IWMI)

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EXECUTIVE SUMMARY

The International Water Management Institute (IWMI) commissioned this study to assess groundwater availability and its current and potential use and impacts at the national scale for Tanzania as part of a wider study that extends across many sub-Saharan African countries.

The study was a desktop study of existing geological, hydrogeological and hydrological data and reports that cover both biophysical and socio-economic aspects of groundwater. The report is based on a thorough review of white and grey literature from various government departments, NGOs, donor reviews and reports, student theses and consultant reports. The study came up with a number of key findings, conclusions and recommendations as highlighted below.

The general geology of Tanzania comprises mainly the Precambrian (Archaean, Proterozoic) and Phanerozoic (Upper Palaeozoic, Mesozoic and Cenozoic) formations. The Archaean rocks are characterized by a granite-greenstone terrain. The Tanzanian Craton covers the central part of the territory up to south and east part of Lake Victoria.

The occurrence of groundwater is largely influenced by geological conditions. Hydrogeologically about 75% of Tanzania is underlain by crystalline basement complex rocks of variable composition and ages, but predominantly Precambrian, which form the basement aquifers (for example the Pangani and Makutopora basins). Other aquifer types include karroo (found in Tanga), coastal sedimentary formation of limestone and sandstone (e.g. Dar es Salaam), and the alluvial sedimentary sequence, which mostly include clay, silt, sand and gravel, and volcanic materials (e.g. Kahe -Pangani basin). The groundwater potential of every type of aquifer differs significantly at the local scale as well as at the basin scale.

The hydrogeology of Tanzania has not been thoroughly studied and owing to that, the quantification of the groundwater resources of the country has not yet been possible because of a lack of requisite data. In most cases, the only available information has been compiled from existing borehole log data.

Groundwater development has concentrated mainly on shallow wells for domestic purposes over a wide part of the country (mainly rural areas). They are also commonly used in the peri-urban fringes where there is no distribution network and places with unreliable supply. Most boreholes are located in the internal drainage basin. The basin is characterized by semi-arid to arid conditions with rainfall less that 550 mm annually, making the dwellers dependent mostly on groundwater as the main source for water supply.

The review has revealed that in areas where the static water level is less than 8 meters, shallow hand dug well fitted with hand pumps is feasible, which on average is about 40% of the Tanzania mainland area.

There are limited extensive studies on recharge in Tanzania and owing to that the recharge rates are not known. However, based on very approximate basin-scale water balance calculations, the total ground water recharge on annual basis is estimated at 3,725 MCM (0.4 %). A general outlook on the various recharge estimates indicates that the values are greatly variable location-wise and are a function of the methods used. Low basin recharge rates implicate on groundwater development potential.

Boreholes drilled for domestic water supplies indicate variable yields. Some boreholes in the Dodoma plain have exceptionally high yields of about $460m^3hr^{-1}$. The average yield of boreholes (excluding Dar es Salaam and dry boreholes) is $11m^3hr^{-1}$. The average static water level of productive boreholes is about 17 metres and the average total depth 62 metres.

The cost for boreholes in Tanzania is about USD 6,000 for hand pumps and USD 12,000 for mechanised systems. These costs include the full facility, i.e. sitting, design, drilling, supervision, construction, and supply of equipment. The drilling cost contributes to only about 50% of the full facility cost.

Groundwater has not been extensively used for irrigation largely due to the following reasons:

- Detailed analysis on groundwater irrigation potential nation-wide has not been thoroughly explored. Most of the estimates are based on surface water information.
- Tanzania still has enough areas that are potential for irrigation using surface water resources. Irrigation high potential area is estimated at 2.1 million ha in gross, as compared with 0.2 million ha currently irrigated.
- There is scant information on the potential of aquifers and yields of individual boreholes.
- Limited groundwater resources management plans.
- The majority of people in the community have an inadequate understanding of groundwater resources and this has led to inappropriate development of groundwater.

The national borehole database is maintained by the MoWI, Directorate of Water Resources in Dodoma. However, the data entry is not consistent; many boreholes have no data recorded and for others the data are incomplete and lack coordinates.

This study recommends detailed groundwater studies be undertaken to assess the recharge and the sustainable groundwater yields, necessary to establish the groundwater potential for irrigation and for the other sectorial uses in Tanzania.

Considering that groundwater in Tanzania is likely to be the key resource to improve the water supply coverage in many areas under the changing climate, the development of groundwater should be carefully managed to make full benefit of its potential, to protect its quality and to guard against over-exploitation of the aquifers.

As a way of improving data management and information sharing, the existing database needs to be transformed into a Management Information Systems (MIS) that is integrated into a Geographic Information System (GIS). Key information like borehole location, groundwater quality, amounts of abstraction, and the hydrogeology should be maintained in the database.

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ACRONYMS AND ABBREVIATIONS

CDR	crude death rate
DADPS	District Agricultural Development Plans
DASIP,	District Agriculture Sector Investment Project
DDCA	Drilling and Dam Construction Agency
GDP	Gross Domestic Product
GFC	Global Financial Crisis
IDB	Internal Drainage Basin
IWMI	International Water Management Institute
IWRM	Integrated water resources management
JICA	Japan International Cooperation Agency
MCM	million cubic metres
MDG	Millennium Development Goal
MIS	Management Information Systems
MKUKUTA	Mkakati wa Kukuza uchumi na Kupunguza Umaskini
MoWI	Ministry of Water and Irrigation
MoEC	Ministry of Education and Culture
NAWAPO	National Water Policy
NBS	National Bureau of Standards
NGO	Non Governmental Organisation
NRWSSP	National Rural Water Supply and Sanitation Programme
NSGRP	National Strategy for Growth and Reduction of Poverty (in Swahili MKUKUTA)
PADEP	Participatory Agricultural Development and Empowerment Project
PRS	Poverty Reduction Strategy Paper
TASAF	Tanzania Social Action Fund
Tsh	Tanzanian shilling
URT	United Republic of Tanzania
USD	United States Dollar
W.D. & I.D	Water Development and Irrigation Division
WRMA	Water Resource Management Act
WUA	Water Users Associations

1.0 BACKGROUND

The International Water Management Institute (IWMI) is undertaking a 3-year research project entitled: *Groundwater in sub-Saharan Africa: Implications for food security and livelihoods*. The research is premised on the view that there are untapped groundwater reserves across the continent. These reserves represent the single most important physical potential to mitigate both climate change and climate variability and to continue contributing to reaching the Millennium Development Goals in sub-Saharan Africa. However, there are key policy and technical constraints that need to be overcome which need to be identified. Tapping this latent resource requires radically different policies and strategies that should be informed by considerably better scientific insights in the physical, socio-economic and institutional potentials and constraints of groundwater use continent-wide at a range of scales ranging from the local through to the regional level.

One of the broad goals of the research project relevant to the research questions listed below is to assess groundwater availability and its current and potential use and impacts at the national scale across sub-Saharan Africa.

1.1 Objectives of the study

The specific objective of this study is to develop a clear and comprehensive report on the status of groundwater in Tanzania.

1.2 Content of the report

This report among other things:

i) Provides information on the main aquifer systems in the country, the extent of the resource and the level of development of groundwater for use in economic development by application of appropriate technologies.
ii) Assesses the groundwater quantity and quality suitable for developing domestic, industrial, agricultural and livestock supplies.
iii) Identifies the productivity, equity, economics, livelihoods, food security impacts of groundwater irrigation at a range of scales ranging from domestic to national.
iv) Strengthens the capacity of the user of the report on the capabilities of the country on practical exploration, development and exploitation of groundwater resources and at the same time outline the drawbacks and constraints to groundwater development.
v) Recommendations to address current issues and knowledge gaps

1.3 Questions addressed by the study

The study addresses the following set of questions:

a) What are the main aquifer systems in the country, and to what is known about their potential for development (rate of borehole completion success, bore yields, current extraction, rates of replenishment, water quality etc)
b) What is the total volume of groundwater used in agriculture and in comparison with total agricultural water use?

c) What percentage of the agricultural economy is now dependent on groundwater use? Are there particular crop/animal types especially dependent on groundwater? How many hectares (and head of livestock) are supported by groundwater use?
d) What is the role of groundwater in social/farming systems. For example, how is groundwater accessed by farmer groups with respect to size, gender, ethnicity? Is agricultural groundwater used mostly on commercial farms, by poor subsistence farmers, or by a range of farmers? With respect to livestock is it used for livestock drinking or fodder production or both?
e) Who are the major groundwater management authorities and what is their role? What institutional arrangements (government policies, legal/regulatory frameworks) govern groundwater irrigation? Are there traditional laws and practices that govern groundwater?
f) What technologies and costs are associated with groundwater extraction (for example, diesel/electric/human powdered, size of pumps, where made, drilling costs, pump costs, operational costs, issues in pump choice)?
g) What are the costs of accessing groundwater across the country? How economic is groundwater for irrigation versus alternative sources?
h) Have there been NGO, donor and government interventions to promote groundwater irrigation, and if so, what has been the outcome?
i) To what extent is groundwater used for rural drinking water supplies and is this related to the extent of small-scale agricultural groundwater development?
j) What are the major issues and problems related to groundwater? What are the main gaps in data and knowledge that would assist in sustainable development of the groundwater resources of the country?

1.4 Methodology

The study was basically a desktop study of existing geological, hydrogeological and hydrological data and reports that cover both biophysical and socio-economic aspects of groundwater. Both the supply-side and demand-side elements of the groundwater economy was adequately and equally covered.

The report is based upon a thorough review of literature that is drawn upon white and grey literature from various government departments, NGOs, donor reviews and reports, student theses and consultant reports.

2.0 INTRODUCTION

2.1 History of groundwater development in Tanzania

Water supply development in Tanzania began around 1930 when the colonial government started to use public funds for the development of water supplies to areas it considered to be of prime interest: townships, mission stations, large estates and trading centres (Maganga *et al*., 2001). After construction these water supply schemes were managed on a self-supporting basis and all users were required to pay for the water they used. Active government involvement in the construction of rural water supply started in the 1950s, when local authorities were required to contribute 25% of the capital cost for water development projects, before the government would release the remaining 75% (Maganga *et al*., 2001).

Earlier on, in 1945 the Department of Water Development was formed. Later, this department assumed irrigation development activities and became the Water Development and Irrigation Division (W.D. & I.D.). In its operations the W.D. & I.D. was concerned with three types of water supplies. The first was development of domestic water supplies for outstations and minor settlements whose construction was financed with central government funds. These supplies were owned by the central government and all users were required to pay a water rate that was calculated to recover capital, operation and maintenance costs. The second type of supply was constructed for Native Authorities (later known as Rural Local Authorities) to meet rural domestic and livestock needs. The Rural Local Authorities were required to pay a portion of the capital costs but operation and maintenance costs were solely the responsibility of the Local Authorities. People who collected water at the domestic point (kiosk) paid for water at a rate that was fixed by the respective Local Authority. The third type was known as prepayment water supplies. These supplies were constructed by W.D. & I.D. only after the client had prepaid the full capital costs of the water supplies. The client in this case could have been another government department, local authority, mission or even private estates (Warner, 1969).

The first Five-Year Plan for Economic and Social Development and the Arusha Declaration (*the "free water" era)* had a significant impact on the management of the rural water supply sector. For example, in 1965 the central government assumed all capital costs of water schemes development. From this date local authorities were left with the responsibility of meeting operational costs, while W.D. & I.D. retained the responsibility for repairs and maintenance provided the Local Authorities made an annual deposit of one percent of the total capital costs of all projects in their areas of jurisdiction (Warner, 1969). Towards the end of 1969 the central government decided to meet the costs of operation and maintenance of all rural water supply projects. This step made the central government responsible for both capital and recurrent costs of all rural water supplies. From this time water became a free good for a rural dweller. In urban centres, on the other hand, consumers who obtained water from metered public kiosks or those with house connections continued to pay for water. It was later decided that consumers who obtain water from public kiosks should also not pay for water. Consequently, people who continued paying for water in the urban areas were those who had either house connection or a water connection in the yard (Warner, 1969).

Subsequently, a new Ministry of Water Development and Power was formed and charged with the responsibility of planning and developing water resources in the country. It was made responsible for urban and rural water supply development as well as energy development throughout the country. It was also at this time (1971) that the ruling Party, The Tanganyika African National Union (TANU) made a major policy decision committing the Government to an objective of providing water in all rural areas so that every rural inhabitant could have easy access to a source of adequate and potable water by 1991 (Maganga *et al*., 2001). In 1980 the government adopted the UN goals for the Water Decade, and mobilised external assistance to prepare regional water master plans and facilitate rapid construction of water supply schemes. Foreign donors responded favourably, and 12 of the country's 20 regions were assigned to various donors. Despite efforts by government and donors, the target of providing every rural dweller with adequate potable water within easy reach was not achieved by 1991. Little attention was given to the ownership of the systems, and local communities looked at the installations as the responsibility of the government (Maganga *et al*., 2001).

Thus, the "free water for all" approach did not meet the intended targets. As noted in the World Bank *Water Sector Study* (1997), in many areas the rate of systems failures exceeded the rate of new construction, yielding lower coverage in the face of population increase despite the high capital cost of the investments. Over 90% of piped schemes ceased operating, mainly due to an inability to provide the required fuel for pumping and to keep the motors and pumps in operating condition. Also, most of the hand-pumps on shallow wells stopped operating for lack of timely maintenance of repair. It was estimated that the installed capacity of constructed schemes could serve only 48% of rural people (World Bank, 1997). Regarding sanitation, the situation was also gloomy. According to World Bank figures (World Bank, 1997), around 68% of rural dwellers obtain their water from traditional sources, which are contaminated and pose health risks, as evidenced by incidence of water borne diseases, such as diarrhoea and cholera (Maganga *et al*., 2001).

In 1986 a conference was organized to review the experiences of implementing the rural water supply programme; to identify and address the problems encountered during the preceding 20 years; and to provide a framework for the sustainable development of water resources to provide an adequate water supply in the country (URT, 1996). The conference started the process of formulating a New Water Policy, which was approved by Parliament in 1991 (URT, 1991). The policy put an end to the "free water era" by introducing the principles of cost sharing in rural areas and full cost recovery in urban areas. Among its features was that:

- In rural areas, village governments were given the responsibility of running their small water supply systems, while the management of larger systems remained the responsibility of regional and in some cases national authorities
- A limited role was assigned to the private sector, stipulating that it might be involved in the provision of water supply services in areas where the Government was not able to do so.

2.2 Water resources issues and water supply

Although in general water resources issues are not the most pressing problems faced by the Water Supply and Sanitation (WSS) sector, WHIRL (2001) identified a range of water resources issues that are increasingly impacting on water supplies. These include:

- *conflicts over water resources*, for example, around the mixed use of irrigation systems. The traditional furrow systems are important sources for domestic supply and animals, as well as for irrigation. While the amounts used for livestock and domestic use are small, this use has important implications for irrigation efficiency because the furrows must be kept flowing to meet a regular demand. Interestingly, professionals working at the 'basin' level in 'resource' management frequently reported no conflict between domestic and other uses (typically concentrating on that between irrigation and hydropower), while those looking at management at the 'local' level (i.e. within irrigation scheme command areas or involved in domestic supply) reported considerable competition and potential for conflict.
- *pollution risks*, for example, the water supply for Dar es Salaam (from the Morogoro mountains) is affected by siltation and chemical pollution associated with commercial agriculture (e.g. sisal processing) in the headwaters. In addition, there is a growing problem of contamination from mercury used in artisanal gold mining.
- *sanitation and development of groundwater in peri-urban and urban areas*. Currently most drinking water is from surface sources, but there is increasing use of groundwater in peri-urban and urban areas. For example, in Dar es Salaam the lack of an efficient distribution network is leading to widespread private development of groundwater, with people resorting to deep and shallow wells, and in some cases selling the water from their wells. The rapid rise in the use of shallow wells is leading to an increased risk of groundwater contamination from pit latrines.

3.0 GENERAL DESCRIPTION OF TANZANIA

3.1 Location

The United Republic of Tanzania (6°00' South, 35°00' East) consists of the mainland and Zanzibar, which is made up of the islands Unguja and Pemba (Figure 3.1). Its total area is 945,090 square kilometers (km^2). The country is bordered in the north by Kenya and Uganda, in the east by the Indian Ocean, in the south by Mozambique and in the west by Rwanda, Burundi, the Democratic Republic of the Congo, and Zambia. The Indian Ocean coast is some 1,300 kilometers (km) long, while in the northwest there are 1,420 km of shoreline on Lake Victoria, in the center-west there are 650 km of shoreline on Lake Tanganyika, and, in the southwest, 305 km of shoreline on Lake Nyasa. The highest point in the country is Mt Kilimanjaro. It also has the largest lake in Africa, Lake Victoria, and the second deepest lake in the world, Lake Tanganyika, forming its boundary.

Source: FAO (http://www.eoearth.org/article/Water_profile_of_Tanzania)

Figure 3.1: Map of Tanzania

3.2 Climate

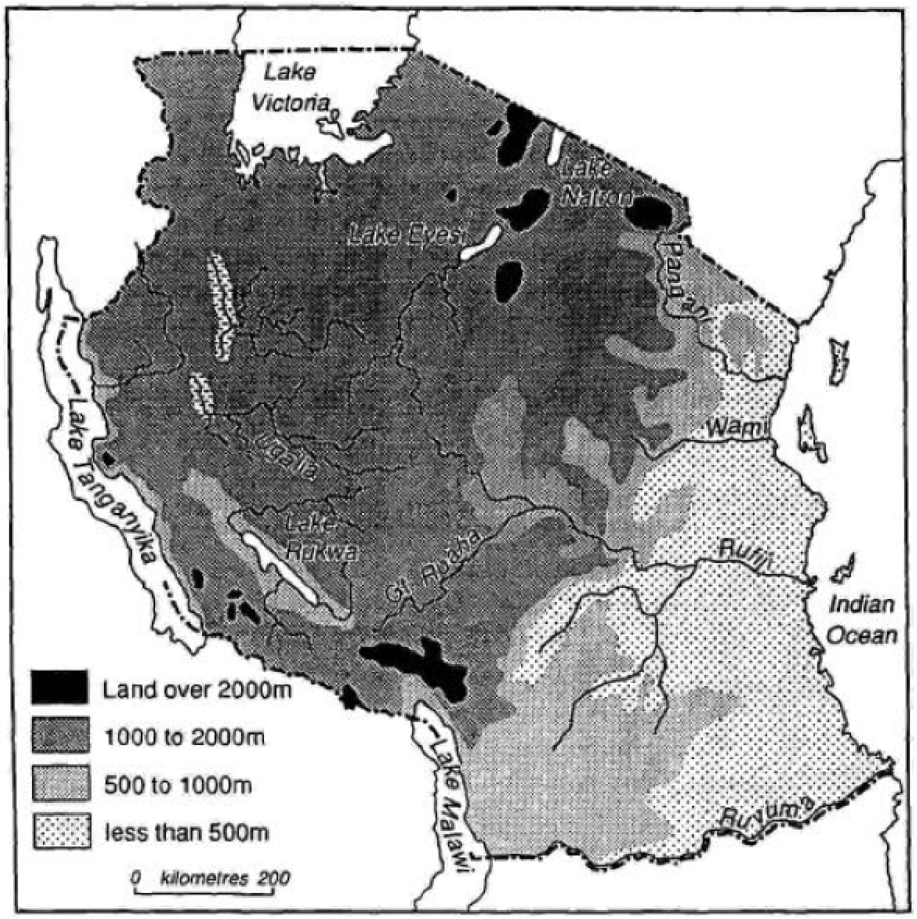
The climate varies from tropical along the coast to temperate in the highlands. There are two types of seasonal rainfall distribution:

- The unimodal type, where rainfall is usually from October/November to April, found in the central, southern and southwestern highlands
- The bimodal type, comprising two seasons: the short rains (Vuli) fall from October to December, while the long rains (Masika) fall from March to June. This type occurs in the coastal belt, the northeastern highlands and the Lake Victoria Basin.

Annual rainfall varies from 500 millimeters (mm) to 1,000 mm over most of the country. The highest rainfall of 1,000 mm to 3,000 mm occurs in the northeast of the Lake Tanganyika basin and in the Southern Highlands. Mean annual rainfall of the country is 1,071 mm. Zanzibar and the coastal areas are hot and humid and average daily temperatures are around 30°C. October-March is the hottest period. Sea breezes however temper the region’s climate and June-September is coolest with temperatures falling to 25°C. In the Kilimanjaro area, temperatures vary from 15°C in May-August to 22°C in December-March.

3.3 Topography

The terrain comprises plains along the coast, a plateau in the central area that ranges between 1000 and 1500 meters above sea level (m a.s.l.), characterised by gently sloping plains and plateau broken by scattered hills and low-lying wetlands (Figure 3.2). The northeast border with Kenya is dominated by Mt. Meru (4565 m a.s.l) and Mt. Kilimanjaro (5895 m a.s.l.). Southwards is the Central Plateau reaching elevations above 2,000 m a.s.l., The mountain range of the Southern Highlands separates the Eastern plateau from the rest of the country. The lowest point is in Lake Tanganyika which is 358 meters below sea level.

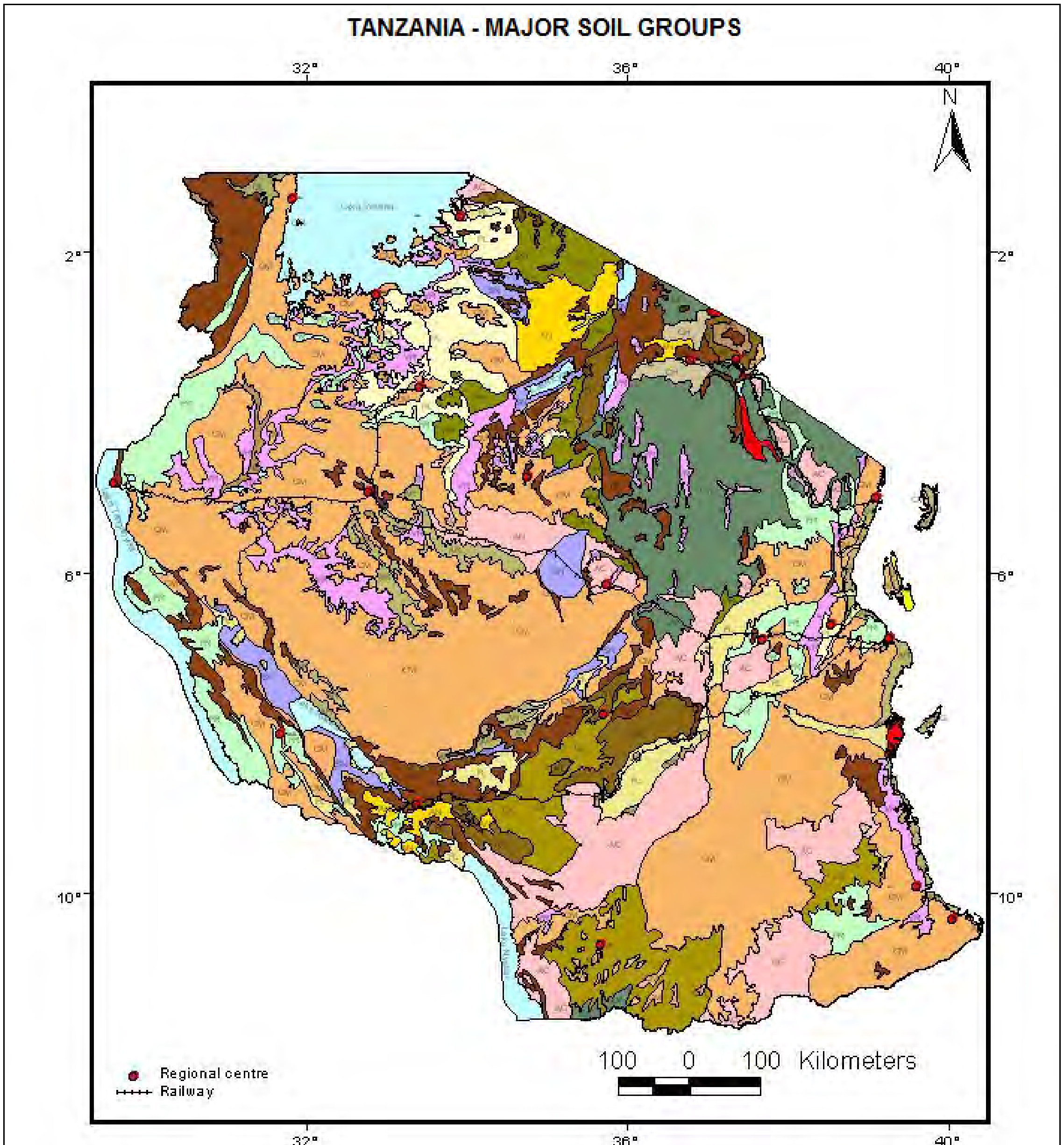


Source: Atlas of Tanzania, 1976

Figure 3.2: Map of Physical Features and Drainage

3.4 Soils

Soils are strongly influenced by the underlying geology and geomorphic history. According to the World Reference Base for Soil Resources (WRB), Tanzania has 19 dominant soil types. Cambisols are the most extensive soils in the country, covering 35.64% of the area (Figure 3.3). They occur mainly in the mid-western and south-eastern parts of the country. The Reference Soil Group of the Cambisols holds soils with incipient soil formation. Beginning transformation of soil material is evident from weak, mostly brownish discolouration and/or structure formation below the surface horizon. The parent material include medium and fine-textured materials derived from a wide range of rocks, mostly in colluvial, alluvial or aeolian deposits. Cambisols are characterized by slight or moderate weathering of parent material and by absence of appreciable quantities of illuviated clay, organic matter, aluminium and/or iron compounds. The other dominant soils by percentage coverage include Acrisols (8.63%), Leptosols (8.11%), Luvisols (7.26%), Ferralsols (6.32%), Vertisols (5.02%) and Lixisols (4.95%).



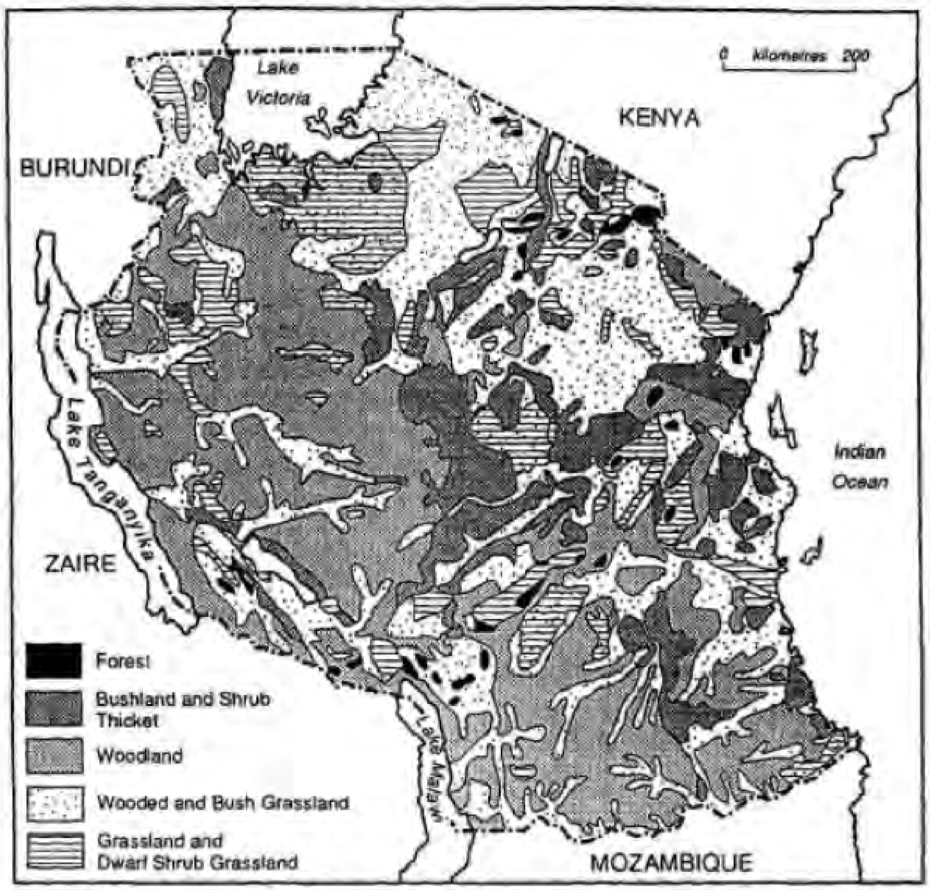
Map code	Major soil group	Sq. km	Percent	Map code	Major soil group	Sq. km	Percent
AC	Acrisols	81643	8.63	LX	Lixisols	46888.61	4.95
AN	Andosols	15904	1.68	LV	Luvisols	68706.15	7.26
AR	Arenosols	21926	2.32	NT	Nitisols	21001.11	2.22
CM	Cambisols	337354	35.64	PH	Phaeozems	22190.10	2.34
CH	Chernozems	4735	0.50	PL	Planosols	28197.84	2.98
FR	Ferralsols	59853	6.32	RG	Regosols	1196.15	0.13
FL	Fluvisols	26223	2.77	SC	Solonchaks	2750.92	0.29
GL	Gleysols	1486.2	0.16	SN	Solonetz	19626.46	2.07
HS	Histosols	3791.5	0.40	VR	Vertisols	47497.85	5.02
LP	Leptosols	76738	8.10	Water bodies		58836.73	6.22

Source: Modified from ARI Mlingano, 2006.

Figure 3.3: Major soil groups of Tanzania

3.5 Vegetation and land use

The vegetation of Tanzania comprises of typical savannah species (Figure 3.4). The country is scattered with wooded grasslands throughout. There are, however, several other types of flora varying from region to region. For instance, there are dense forests of hardwood and softwood trees in the places where rainfall is high; where rainfall is less and the land dry bushes and thickets thrive; the highlands are grassy expanses and the coastal regions are blanketed with mangroves. Generally, land cover is dominated by woodland, grassland and bushland, which account for about 80% of the total land area. Cultivable area is estimated to be 40 million ha, or 42% of the total land area.



Source: Adapted from Handbook of Natural Resources of East Africa, ¼.0 million map of E. Africa, E. African Literature Bureau, Nairobi, 1976

Figure 3.4: Major vegetation of Tanzania

3.6 Surface water resources

Tanzania has nine major drainage basins (Figure 3.5) that, according to the recipient water body, can be categorized as follows:

- Draining to the Mediterranean Sea (the Lake Victoria basin, which is part of the Nile River basin).

- Draining to the Indian Ocean (the Pangani River basin; the Ruvu/Wami River basin; the Rufiji River basin; the Ruvuma River and Southern Coast basin, and the Lake Nyasa basin, which is part of the Zambezi River basin).
- Draining to the Atlantic Ocean (the Lake Tanganyika basin, which is part of the Congo River basin).
- Rift Valley (endorheic) basins, of which amongst others (the Lake Eyasi and Bubu depression; Lake Manyara, and the Lake Rukwa basin).

River regimes follow the general rainfall pattern. River discharge and lake levels start rising in November-December and generally reach their maximum in March-April with a recession period from May to October/November. Many of the larger rivers have flood plains, which extend far inland with grassy marshes, flooded forests, and ox-bow lakes.

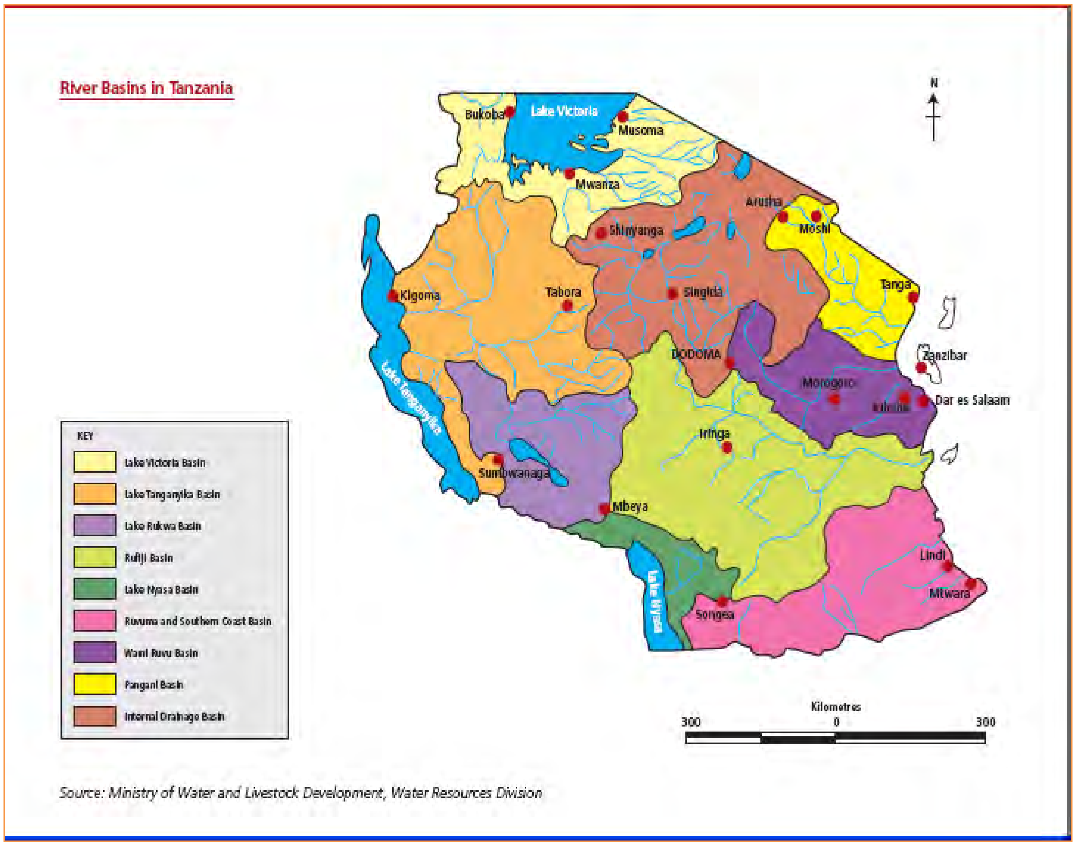


Figure 3.5: Surface Water Basins in Tanzania

About 5.7 percent of the total land area of the United Republic of Tanzania is covered by three large lakes, which also form the border to neighbouring countries:

- Lake Victoria, which is part of the Nile River basin, is shared with Kenya and Uganda. Its total area is 68,800 km^2, of which 51 percent belongs to the United Republic of Tanzania.

- Lake Tanganyika, which is part of the Congo River basin, is shared with Burundi, Democratic Republic of Congo, and Zambia. Its total area is 32,900 km^2, of which 41 percent belong to the United Republic of Tanzania.
- Lake Nyasa, is shared with Malawi and Mozambique. Its total area is 30,800 km^2, of which the United Republic of Tanzania claims 5,569 km^2 or 18 percent.

Other lakes include Lake Rukwa, Lake Eyasi, Lake Manyara, Lake Natron, Lake Balangida. Also there are dams that supply water for Hydro Electric Power generation and for other uses.

In the 1970s, 21 small-scale earthfill-type dams were constructed mainly on seasonal rivers in the Tabora region for irrigation and domestic supply purposes. All except seven of them suffer from serious sedimentation. In addition to these dams, there are many smaller dams over the whole land, called Charco dams, for irrigation, domestic, and livestock purposes. In general, dam construction is largely restricted by hydrological and topographic conditions.

Total renewable water resources amount to 93 cubic kilometers per year (km^3yr^{-1}), of which 84km^3yr^{-1} are internally produced, and 9 km^3yr^{-1} are accounted for by the Ruvuma River, which flows over the border from Mozambique (Ramonyai and Konstant, 2006). Renewable groundwater resources are estimated at 30 km^3yr^{-1}, of which 4 km^3yr^{-1} are considered to directly interact with surface water.

3.7 Water Use

Total water withdrawal in mainland Tanzania was estimated for the year 2002 to be 5,142 million cubic meters (m^3). Agriculture consumes the largest share with 4,624 million m^3 (almost 90 percent of total) of which 4,417 million m^3 for irrigation and 207 million m^3 for livestock, while the domestic sector uses 493 million m^3 (Figure 3.6). Total water withdrawal by the domestic sector and irrigation in Zanzibar is estimated to be about 42 million m^3. Of this, withdrawal on Unguja Island is 33 million m^3 and on Pemba Island it is 9 million m^3. Industry in Tanzania consumes an estimated 25 million m^3.

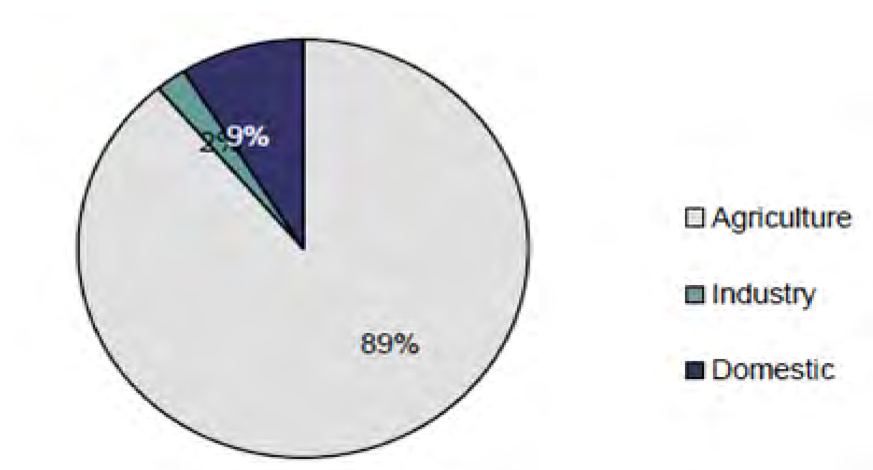


Figure 3.6: Surface water withdrawals by Sector, Tanzania, 1994

3.8 Socio-economic context

The population density is 40 inhabitants/km^2. The vast majority of the population lives inland, far away from the coastline. Poverty is concentrated in the rural areas; however, urban poverty has also grown along with rapid urbanization. The national poverty rate was about 36% in 2002 (Ramonyai and Konstant, 2006). In 2002, 92% of the urban and 62% of the rural population were using improved drinking water sources.

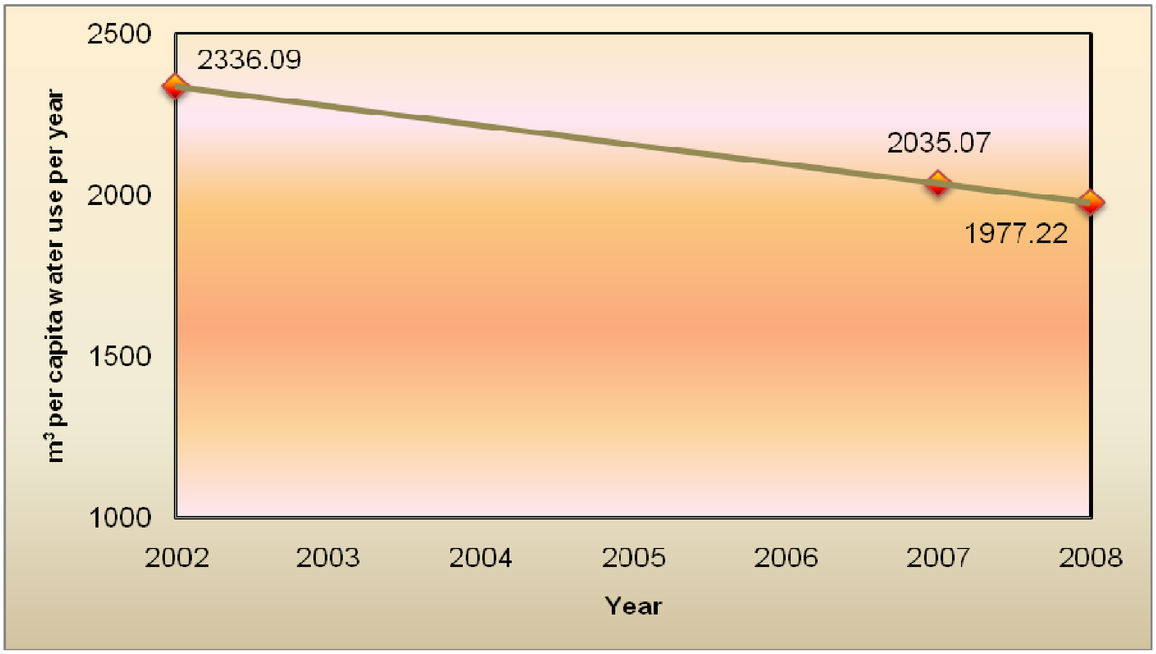
3.8.1 Population growth and development

The 2002 Population and Housing Census showed that the Population of Tanzania increased from 23.1 million in 1988 to 34.4 million in 2002 with an average growth rate of 2.9 percent per annum. The population projections show that Tanzania is expected to reach 63.5 million in 2025 (URT, 2006). The proportion of the population aged below 15 years was about 44 percent while those aged 65 years and above was 4 percent, indicating that Tanzania has a young population. This youthful age structure entails a larger population growth in future, as the young people move into their reproductive life irrespective of whether fertility declines or not (URT, 2006).

An important feature of the population profile is its spatial distribution over the national territory. The analysis of population distribution by region carried out on all past censuses indicates that about two-thirds of the population is concentrated in a quarter of the land area. According to the 2002 Population and Housing Census population distribution differs between regions where by if ranges between 12 persons per square kilometer as observed in Lindi regions, to 1,700 persons per sq. km as observed in Urban West (Zanzibar) region , and to as high as 1,793 in Dar es Salaam region (URT, 2006). The majority of the population (77 per cent of all Tanzanians) still lives in rural areas. However, the urban population has been growing at a rapid rate of more than 5 per cent per annum over the past three decades. This rapid growth has been caused mainly by rural-urban migration than any other factor.

The main components of population growth in any country are fertility, mortality and migration (URT, 2006). In Tanzania, fertility and mortality are the most important factors influencing population growth at national level. Previous censuses have shown that the net international migration component has been negligible. However, there are certain areas in Tanzania where migration have shown a big impact on population growth particularly the areas receiving refugees.

Fertility rate in Tanzania has declined slightly from 5.8 children per woman during her childbearing age in 1996 (NBS&MI, 1997) to 5.7 children per woman in 2004 (NBS&ORC, 2005). In 2004, Mainland Tanzania recorded 6.5 and 3.5 births per woman in rural and urban areas, respectively. Differences related to education are inversely much wider. Fertility rate for women with no education was 6.9, with primary education 5.6 and with secondary and higher education 3.2 (NBS&ORC, 2005). In the case of Zanzibar, the Total Fertility Rate (TFR) declined from 6.9 in 1996 (NBS&MI, 1997) to 5.3 in 2004 (NBS&ORC, 2005). The Infant Mortality Rate (IMR) was reported to be 99.8 per 1000 in 2003 (AfDB, 2010).



Source: World Bank, World Development Indicators (http://data.worldbank.org/data-catalog/world-development-indicators?cid=GPD_WDI)

Figure 3.7: Trend in available renewable freshwater flows in rivers and groundwater from rainfall, in cubic meters per capita

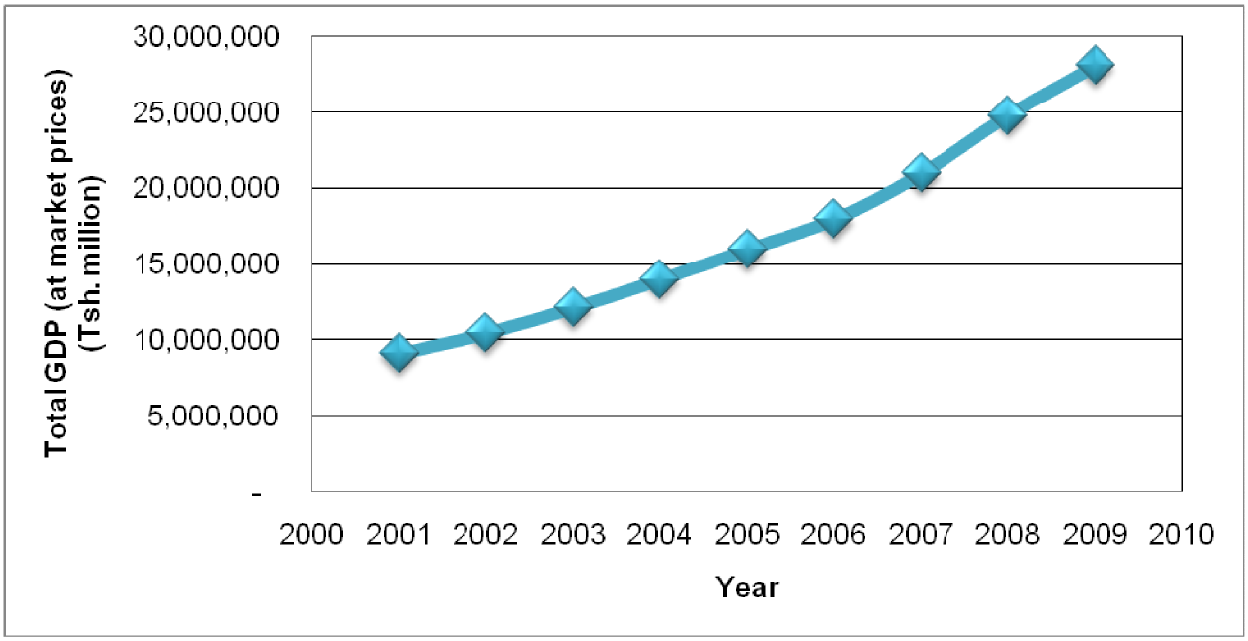
Rapid population growth impacts on the water resources coverage and because of that, the per capita water use has been decreasing over the time. The Wold Bank indicators show that in 2008 (Figure 3.7) Tanzania had 1,977.22 m^3 per capita water use per year, however due to population growth, increase in water demand to meet requirements for various socio-economic activities, pollution and climate change, this amount is going to decrease to about 1,500 cubic metres per capita per annum by 2025. According to AfDB, (2010), the water supply coverage is estimated at 73 % for urban areas and 53 % for rural areas and sustained sanitation coverage is estimated at around 50 %.

3.8.2 Gross Domestic Product

Tanzania economy indicated stable growth between early 2000s and the recent period (Figure 3.8). Real Gross Domestic Product (GDP) growth which averaged 4.5 percent during 1996 – 2001, rose to 6.2 percent in 2002, 5.7 percent in 2003, 6.7 percent in 2004 and 6.8 percent in 2005. This growth owes much to improvements in almost all sectors of the economy as well as to a stable macroeconomic management. Per capita GDP growth was negative during the first half of the 1990s, but has accelerated significantly and reached 4 per cent in recent years.

In 2009, the real Gross Domestic Product (GDP) grew by 6.0 percent compared to 7.4 percent in 2008 (URT, 2010). The slowdown in growth for 2009 was attributed to the impact of the Global Financial Crisis (GFC) as well as the 2008/09 drought which affected agricultural production, hydro power generation as well as industrial production; all of which have a significant share in total GDP. However, the growth rate of electricity and gas, communication and education sub-economic activities increased. The GDP amounted to Tsh. 28,212,646 million at current prices in

2009, which was equivalent to Tsh. 15,721,301 million at 2001 constant prices. Since the population of Tanzania Mainland was estimated at 40.7 million in 2009, the per capita income was Tsh. 693,185 in 2009 at current prices compared to Tsh. 628,259 in 2008, equivalent to 10.3 percent increase (URT, 2010). The increased in per capita income was attributable to increase in agricultural, hunting and forestry economic activities that grew by 3.2 percent compared to 4.6 percent in 2008. The growth rate of crops sub activity decreased to 3.4 percent in 2009 from 5.1 percent in 2008. This was mainly attributed to drought during the 2008/09 season. The growth rate of livestock sub activity was 2.3 percent in 2009 compared to 2.6 percent in 2008. The decrease was due to drought during the 2008/09 season particularly in the Northern part of Tanzania that led to inadequate pasture and water for livestock, and eventually decline in the price of livestock's products Forestry and hunting sub activities grew by 3.5 percent in 2009 compared to 3.4 percent in 2008.



Source: National Bureau of Statistic cited in URT (2010)

Figure 3.8: Trend in total GDP at current (2009) market prices

3.9 Economy, agriculture and food security

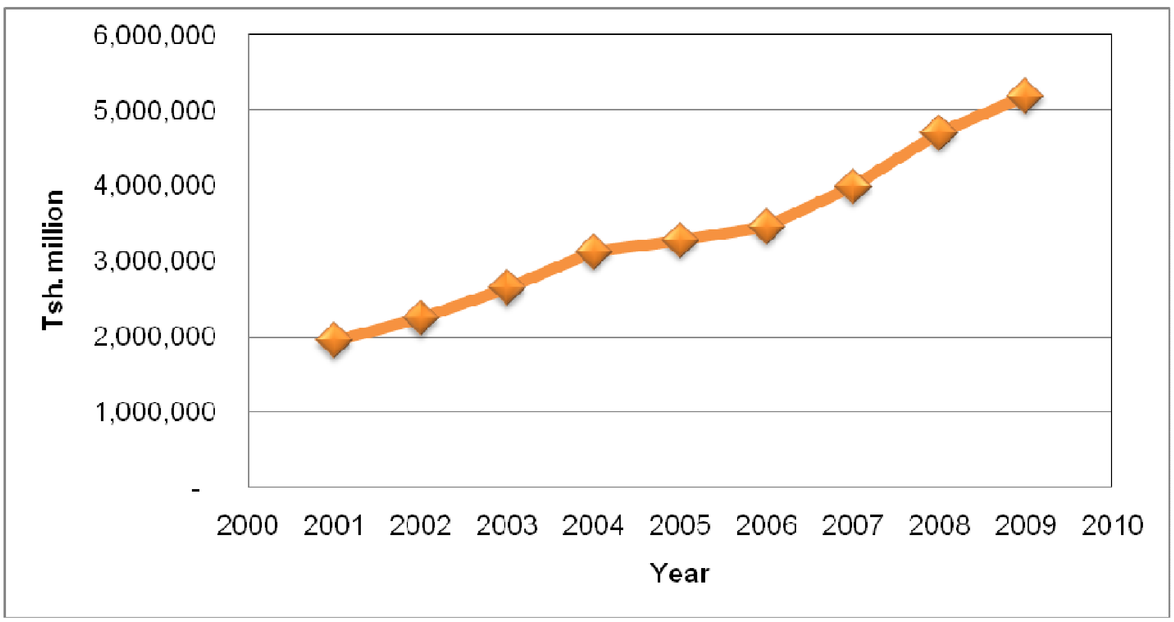
Significant measures have been taken to liberalize the Tanzanian economy along market lines and encourage both foreign and domestic private investment. Beginning in 1986, the Government of Tanzania embarked on an adjustment program to dismantle socialist economic controls and encourage more active participation of the private sector in the economy. The program included a comprehensive package of policies which reduced the budget deficit and improved monetary control, substantially depreciated the overvalued exchange rate, liberalized the trade regime, removed most price controls, eased restrictions on the marketing of food crops, freed interest rates, and initiated a restructuring of the financial sector.

The country's GDP was US$ 9.9 billion in 2003, and the value added in agriculture was 43.4% of GDP (Figure 3.9). The GDP annual growth rates by kind of economic activity at constant

2001 prices (Table 3.1) indicate decreasing and increasing patterns to some of the economic activities.

The agricultural sector continues to lead economic growth, in spite of the recent emergence of new high-growth sectors of mining and tourism, and it continues to have the highest impact on the levels of overall economic growth and food security. Agriculture provides work for 14.7 million people, or 79% of the total economically active population and 54% of agricultural workers are female. Small-scale subsistence farmers comprise more than 90% of the farming population, with medium- and large-scale farmers accounting for the rest.

Main food crops grown are maize, sorghum, millet, paddy, wheat, sweet potato, cassava, pulses and bananas. Maize is the dominant crop with a planted area of over 1.5 million ha during recent years, followed by paddy with more than 0.5 million ha over recent years. The main agricultural products exported by Tanzania are green coffee, cashew nuts and tobacco that, in 2001, represented about 41% of all agricultural exports. The main agricultural products imported are wheat and palm oil. In recent years, the country has not been self-sufficient for cereals mainly due to crop failure as a result of change in onset of rainfall, amount and distribution within the growing season, but it is self-sufficient in non-cereals at a national level.



Source: National Bureau of Statistic cited in URT (2010)

Figure 3.9: Agricultural GDP (million shillings) at 2009 market prices

Table 3.1: GDP annual growth rates by kind of economic activity at constant 2001 prices

GROSS DOMESTIC PRODUCT BY KIND OF ECONOMIC ACTIVITY - ANNUAL GROWTH RATES

At constant 2001 prices

Percentages

ECONOMIC ACTIVITY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Agriculture, Hunting and Forestry	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Crops	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Livestock	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hunting and Forestry	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fishing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Industry and construction	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mining and quarrying	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Manufacturing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Electricity, gas	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Water supply	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Construction	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Services	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Trade and repairs	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hotels and restaurants	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Transport	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Communications	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Financial intermediation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Real estate and business services	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Public administration	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Education	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Health	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other community, social and personal services	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Gross value added at constant basic prices	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Add Taxes on products	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GDP (Constant prices)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Source: National Bureau of Statistic cited in URT (2010)

3.10 Fisheries

Tanzania being a coastal state is endowed with fishery resources. She has both marine and inland fisheries potential. The marine water covers 64,000 square kilometers which includes the Indian Ocean and the Exclusive Economic Zone which covers 223,000 square kilometers. The fresh water includes the riparian shared waters of East African great lakes namely Lake Victoria, Tanganyika and Nyasa. The country has also other small natural lakes, man-made lakes, river systems and many wetlands with fish potential. All these water cover 58,000 square kilometers. The present annual fish catch is about 350,000 metric tons (http://www.tanzania.go.tz/naturalresourcesf.html).

The number of fishermen who are permanently employed is about 80,000 and few others obtain their livelihood from the sector by being employed in the fishing and fishery related activities. The artisanal fishermen produce about 90% of the total fish catch in the country; only 10% is derived from industrial fishing. Most of the fish caught is consumed locally while Nile perch; sardines and prawns are for exports.

Fishery contributes about one third of the animal protein or 30% of the total intake to the Tanzanian population. It is a source of employment, livelihood to the people, recreation, and tourism in order to generate foreign exchange. The contribution of the sector to GDP for the past five years has been staggering between 1.6 and 3.1%. For example, in 2009, fishing activities grew by 2.7 percent compared to 5.0 percent in 2008. The decline was attributed to poor fishing gears, destruction of fish hatcheries and stiff competition in the European market especially from China, and Vietnam which use modern technology and aquaculture. The contribution of fishing activities in GDP was 1.4 percent in 2009 compared to 1.2 percent in 2008 (URT, 2010).

In 2009, a total of 344,567.2 tons of fish worth about Tsh. 408 billion were harvested compared to 350,311.4 tons worth Tsh. 235.3 billion in 2008. In addition, 174,540 artisanal fishermen participated in fishing using 56,164 fishing vessels compared to 170,038 artisanal fishermen using 52,174 fishing vessels in 2008. Out of that, 136,933 fishermen operated in fresh water using 48,221 fishing vessels and harvesting 299,729.1 tons of fish worth Tsh. 354.4 billion. Artificial artisans from the Coastal zone were 37,607 harvested 44,838 tons of fish worth Tsh. 56.6 billion using 7,943 fishing vessels (URT, 2010).

In 2009, a total of 41.1 million kilograms of fish and 53,188 pieces of aquarium and live fish worth Tsh. 1,136.9 billion were exported compared to 51.4 million kilograms and 33,066 aquarium and live fish in 2008. Receipts from aquarium and live fish exports were Tsh. 6.3 billion in 2009 compared to Tsh. 6.6 billion in 2008. Nile perches exports declined by 24.3 percent to 29,308,384 tons worth Tsh. 130.8 billion compared to 38,721,422.2 tons worth Tsh. 180.4 billion in 2008 (URT, 2010).

3.11 Livestock

Tanzania is endowed with abundant natural resources, which include land, forage and a large livestock resource base. Out of the total 88.6 million hectares of land resource, 60 million hectares are rangelands suitable for livestock grazing, able to carry up to 20 million Livestock Units (Njombe and Msanga, *undated*). However, due to tsetse infestation and other constraints, only 40% of the rangelands are utilised for grazing 18.5 million cattle; 13.1 million goats and 3.6 million sheep. Other major livestock species kept in the country include 1.2 million pigs and 53 million poultry. More than 90% of the livestock population in the country is of indigenous types (Table 3.2), kept in the traditional sector, having a characteristically low productivity yet well adapted to the existing harsh environment including resistance to diseases.

Livestock is among the major agricultural sub-sectors in Tanzania. Out of the 4.9 million agricultural households, about 36% are keeping livestock (35% are engaged in both crop and livestock production while 1% are purely livestock keepers). The industry accounted for 5.9 percent to total GDP in 2006, of which beef, dairy and other stock provided 40%, 30% and 30% respectively (Njombe and Msanga, *undated*). The contribution of livestock is not limited to its share in the total GDP but also play other important roles such as contribution to national food supply (meat, milk and eggs), and food security; acts as a source of cash income, employment and an inflation free store of value. It also provides manure and draught animal power thus contributing to sustainable agriculture. In addition, livestock play an import substitution role in the consumption of livestock products in the country. Despite its importance, to date the industry's contribution to the national economy is still dismal compared to other sectors of the economy.

Table 3.2: Livestock population in Tanzania by species and region

Region	Cattle	Goats	Sheep	Pigs*	Indigenous chicken
Dodoma	807,711	696,349	121,371	43,835	1,634,079
Arusha**	1,523,238	1,795,227	717,620	58,657	1,593,466
Kilimanjaro	603,401	609,975	267,612	155,070	1,356,781
Tanga	309,262	320,156	81,798	6,281	1,751,278
Morogoro	114,172	305,734	57,661	44,986	2,018,227
Pwani	129,255	68,514	7,900	3,673	1,254,145
Dar es Salaam	20,504	73,789	7,484	12,993	182,449
Lindi	6,630	102,325	8,075	4,956	1,075,122
Mtwara	22,811	262,959	22,986	6,293	704,619
Ruvuma	94,090	981,935	60,834	134,951	1,536,330
Iringa	1,201,434	361,320	98,672	180,904	2,045,274
Mbeya	845,652	371,289	71,251	229,465	2,493,796
Singida	1,810,098	1,236,046	454,995	6,375	1,643,973
Tabora	1,817,236	910,469	247,448	6,286	2,498,191
Rukwa	411,467	252,501	13,111	58,754	1,114,556
Kigoma	129,713	477,610	43,068	23,698	785,308
Shinyanga	3,818,106	2,083,659	833,743	3,266	2,935,380
Kagera	840,978	862,221	64,354	145,761	905,549
Mwanza	2,186,821	875,890	167,031	610	2,580,891
Mara	1,285,959	658,268	195,397	2,409	1,505,422
Total	**17,978,538**	**13,306,236**	**3,542,411**	**1,129,223**	**31,614,836**

Source: MLD 2006/2007 cited in Njombe and Msanga, *undated* [http://www.mifugo.go.tz/documents_storage/LIVESTOCK%20INDUSTRY%20DAIRY%20DEVELOPMENT%20IN%20TANZANIA%20-%20LATEST3.pdf]
* National Sample Census of Agriculture 2002/2003
**Includes Arusha and Manyara

3.12 Industrial sector

Accounting for only about 10% of GDP, Tanzania's industrial sector is one of the smallest in Africa. It has been hit hard recently by persistent power shortages caused by low rainfall in the hydroelectric dam catchment area, a condition compounded by years of neglect and bad management at the state-controlled electric company. Management of the electric company was contracted to the private sector in 2003.

The industrial sector comprises manufacturing, mining and quarrying, construction, and utilities (electricity and water supply) sub-sectors, whose industries are categorized into formal and informal. The main industrial activities include producing raw materials, import substitutes, and processed agricultural products. The mining and quarrying sub activity grew by 1.2 percent in

2009 compared to 2.5 percent in 2008. The decrease was due decline in minerals prospecting and investment following economic downturn of 2008 (URT, 2010).

The value of mineral exports was USD 1,217.3 million in 2009 compared to USD 1,098.8 million in 2008, equivalent to an increase of 10.8 percent. The increase was attributed to increase in gold production and prices of gold and diamond in the world market.

Manufacturing activities grew by 8 percent in 2009 from 9.9 percent in 2008. The decline was largely attributed by the world economic crisis. The contribution of manufacturing activities to GDP increased from 7.8 percent in 2008 to 8.6 percent in 2009.

In 2009, advisory services related to business development were provided to 21,922 entrepreneurs compared to 6,139 in 2008, equivalent to an increase of 257 percent. Out of that, 10,203 entrepreneurs were trained on food and leather processing. In addition, 2,152 entrepreneurs participated in trade fairs in 2009 and sell goods worth shs.1.72 billion. Likewise, credit extended to small entrepreneurs amounted to Tshs 3.6 billion in 2009 compared to Tshs 1.2 billion in 2008. The provision of credit facilitated creation of 13,300 employment opportunities in 2009 compared to 3,669 in 2008 (URT, 2010).

In 2009, the growth rate of construction activities was 7.5 percent compared to 10.5 percent in 2008. The growth was mainly attributed to increase in construction of roads and bridges; residential and non- residential building; and land development. The contribution of construction activities to GDP was 7.9 percent in 2009 compared to 7.7 percent in 2008 (URT, 2010).

3.13 Poverty

In recent periods, an improvement in the quality of life of Tanzanians through better incomes and reduced levels of poverty has been realized. For example, the level of household consumption changed little between 2000/01 and 2007. Nationally, household consumption per capita increased by only 5%, implying an average change of 0.8% annually (URT, 2009a). Consumption levels have changed very little from 2000/01 to 2007. Almost 98% of Tanzanians have extremely low consumption levels, less than TShs 30,000 per month (at 2001 prices), which is equivalent to TShs 58,000 in 2007 prices. Moreover, approximately 80% consume less than TShs 20,000 per month (at 2001 prices) or TShs 38,600 in 2007 prices, which is equivalent to TShs 1,380 per day (URT, 2009a). Table 3.3 presents a summary of key poverty indicators, the baseline conditions and the targets as per the National Strategy for Growth and Reduction of Poverty (NSGRP) (in swahili MKUKUTA).

Table 3.3: Poverty indicators, baselines and targets

Indicator %	Baseline Estimate	Baseline Year	Trend 2001	Trend 2002	Trend 2003	Trend 2004	Targets PRS 2003	Targets MKUKUTA 2010
INCOME, EMPLOYMENT								
Population below basic needs poverty line	36	2000/01	-	-	-	-	30	19
Population below the food poverty line	19	2000/01	-	-	-	-	15	10
GDP growth rate	4.9	2000	5.7	6.2	5.7	6.7	6	6-8
Agricultural growth rate	3.4	2000	5.5	5.0	4.0	6.0	5	10
Inflation rate	5.9	2000	5.2	4.5	3.5	4.1	4	4
Working age population currently unemployed	13	2000/01	-	-	-	-		7
NUTRITION								
Stunting in under-fives	44	1999	-	-	-	38		20
EDUCATION								
Primary net enrolment rate	59	2000	66	81	89	91	70	
Girls	60		66	79	87	90		99
Boys	59		66	82	90	91		99
Cohort completing standard 7	70	2000	74	-	72	79		90
Pupils passing standard 7 exams							50	
Girls	15	2000	21	20	33			60
Boys	29		36	34	48			60
Secondary net enrolment rate, forms 1-4							7	
Girls	-	-	-	7	7	9		50
Boys	-	-	-	6	6	7		50
Adult literacy rate (15 +)	71	2000	-	69	-	-	100	
Female	64			62				80
Male	80			78				80
HEALTH, SURVIVAL								
Under-five mortality rate (per 1,000 live births)							127	79
DHS	147	1999[86]	-	-	-	112[86]		
Census			-	162[86]	-	-		
1 year-olds immunised against measles	78	1999	-	-	-	80	85	
DPT (3)	81		-	-	-	86	85	
Maternal mortality ratio (per 100,000 live births)	529	1996[86]	-	-	-	578[86]	450	265
Births attended by trained personnel	36	1999	-	-	-	46	80	80
HIV/AIDS								
HIV in pregnant women 15-24 years	-	-	-	-	6.8	-	-	5
WATER AND SANITATION								
Population with access to clean and safe water								
Rural	-	-	-	42	-	-	55	65
Urban	-	-	-	85	-	-	-	90
Population with access to basic sanitation	-	-	-	91	-	-	-	95

Source: (NBS 2002, HBS 2000/01; URT Economic Surveys, various; NBS/Macro International 1999 and 2005; NBS 2003, Population and Housing Census 2002, MoEC Basic Statistics Education, various, cited in URT, 2009a)

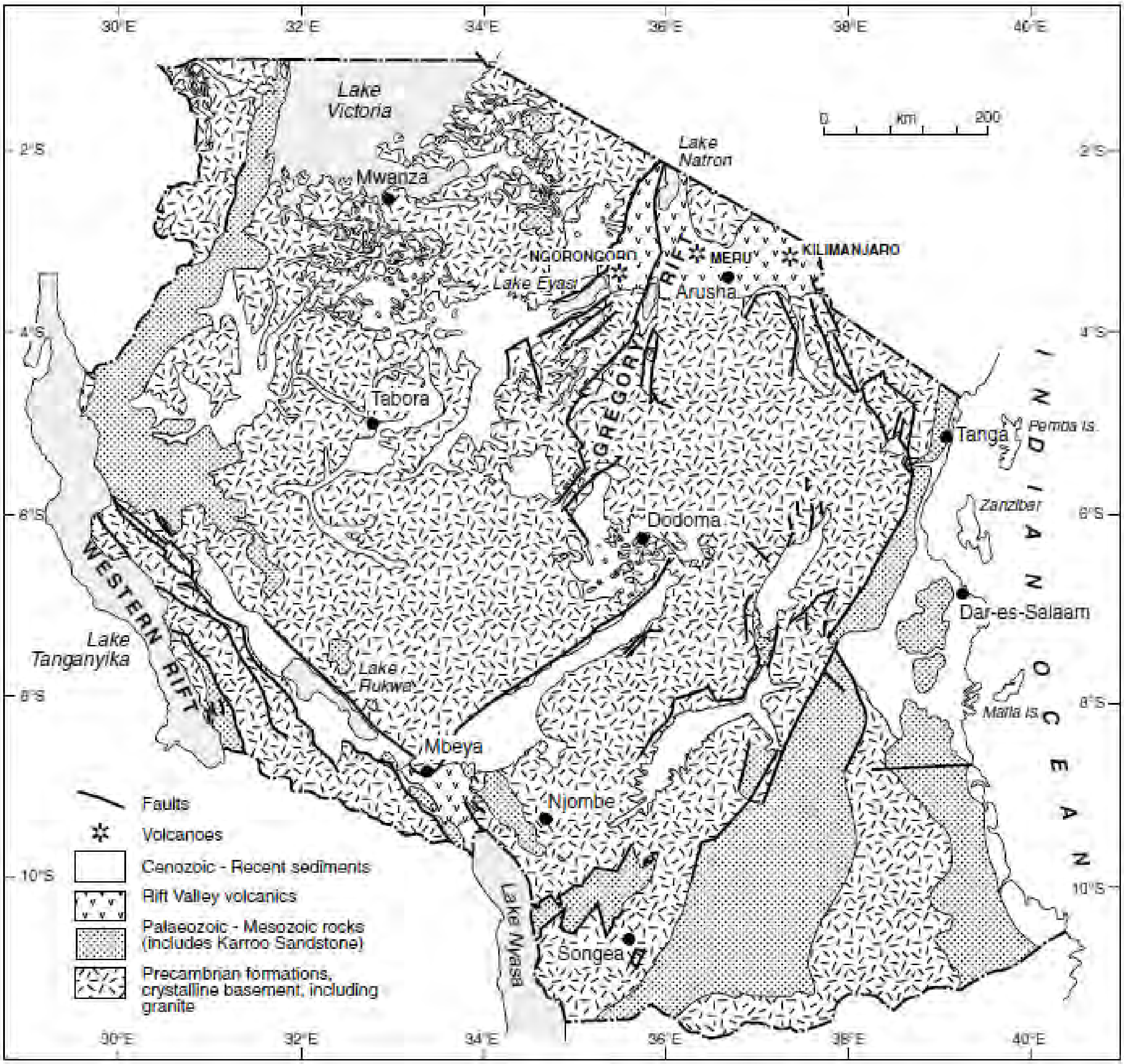
According to URT (2009a), the consumption inequality between 2000/01 and 2007 remained at close to the same level – the poorest quintile of households experienced a small fall in consumption (-2%), while the least poor group experienced a slight increase (7%).

MKUKUTA targets to reduce the number of Tanzanians living in poverty by 50% from 1990 to 2010, and Millennium Development Goal 1 (MDG1) aims to achieve this reduction by 2015. In 1991/92 the poverty head count was 38.6%, so the objective is to reduce poverty to 19.3%. The MKUKUTA target to halve poverty by 2010 is out of reach, and achieving MDG1 is extremely ambitious even though a relatively large proportion of households have consumption levels not far below the basic needs poverty line (URT, 2009a). If it were possible to move these households across the poverty line, the MDG objective might be achieved. However, to achieve this goal, consumption levels must increase significantly. An annual real consumption growth of 3.2% per capita will be needed, compared with the 0.8% which has been achieved from 2000/01 to 2007. This is not impossible but will require unprecedented real consumption growth in Tanzania between now and 2015. Since Tanzania's level of income inequality is currently low, even by international standards, redistribution of income is not likely to be effective in achieving significant reductions in poverty (URT, 2009a). Continued high rates of economic growth over the long term will be required.

4.0 GROUNDWATER RESOURCES IN TANZANIA

4.1 Geology of Tanzania

The general geology of Tanzania comprises mainly the Precambrian (Archaean, Proterozoic) and Phanerozoic (Upper Palaeozoic, Mesozoic and Cenozoic) formations. The Archaean rocks are characterized by a granite-greenstone terrain. The Tanzanian Craton covers the central part of the territory up to south and east part of Lake Victoria. A simplified geological map of Tanzania is presented in Figure 4.1.



Source: British Geological Survey and Water Aid (www.wateraid.org/documents/**tanzania**gw.pdf)

Figure 4.1: Simplified geological map of Tanzania

Precambrian Basement Rocks

The Precambrian Basement Rocks of Tanzania consist of Dodoman System, Nyanzian System, Kavirondian System, Usagaran System, Bukoban System and Plutonic Rocks (JICA, 2008).

i) Dodoman System (Archean)

The Dodoman system is the oldest formation in Tanzania, which consists of schist gneiss and migmatite. It is distributed around Dodoma Region. It consists of metamorphic rocks which are metamorphosed from sedimentary and granite rocks in Archean. The rocks for Dodoman system are very dense and not easily weathered. The recharge mechanism is through the fracture zone. Drilling depths is estimated to be 70-120 m.

ii) Nyanzian System (Archean)

The Nyanzian system consists of metamorphic rock, which was metamorphosed from sedimentary and igneous rocks. They are distributed in Shinyanga, Nzega, Igunga and Iramba districts. Discriminative rock is banded ironstone which is distributed in Igunga District, and schist and quartzite. Banded ironstone is very dense and hard, likewise the Schist and quartzite are also dense with possibilities for groundwater fissure parts of the rocks. Nyanzian system is surrounded by granite at many places and these are areas have many fractures that are suitable for groundwater recharge. Drilling depths is estimated to be 40-100 m.

iii) Kavirondian System (Archean)

The Kavirondian system consists of quartzite and phyllite. Outcrops of the rocks are confined at limited area near Nzega.

iv) Usagaran System (Archean)

Metamorphic rock called "Usagaran" as part of Mozambique metamorphic belt is distributed in the north part of Arusha, Manyara, and Dodoma regions. The Usagaran system consists of marble, schist, gneiss and migmatite. It consists of older granitic and sedimentary rocks that were metamorphosed by the orogenic movement of intrusion of granites. These rocks crop out the large area of the eastern part of Internal drainage basin. Hydrogeological condition is almost the same of that of granite. Gneiss which is originated in intrusion of granite is easier to be weathered than granite, and it forms wide pediplain. Maasai steppe is one of such kind of pediplains. Recharge in these areas is mainly through faults or lineaments with high possibility for groundwater development. Drilling depths is estimated to be 40-250 m.

v) Bukoban System (Proterozoic)

The Bukoban system consists of sedimentary rocks; mudstone, shale, sandstone, etc. Exposures of the rocks are confirmed at the limited area in the southern part of the Bahi swamp.

vi) Plutonic Rocks (mainly Archean)

Plutonic rocks consist of granite and granodiorite, gneissose or migmatitic rocks. Plutonic rocks are widely distributed from the central to the western part of Internal Drainage Basin.

Kainozoic (Cenozoic) Formations

During late Neogene, lacustrine sediments, terrestrial sediments, fluviatile sediments, marine sediments and alluvial sediments deposited in the lakes and shallow basins formed by the warping of the surface that accompanied rift-faulting movements. These sediments are distributed in the centre of each basin and characterized by low plane in topography.

Volcanic Rocks

From the central to the north-western part of Tanzania, extensive volcanic activity in association with rift-faulting movements can be seen from Mt. Hanang, Mt. Kilimanjaro and northward into Kenya. These huge volcanic massifs consisting of extensive alkaline lava and pyroclastics are accumulated. These volcanic activities have been continuing in small scale. In general, alkaline type volcanic rocks have high volatile content such as H_2O, CO_2, F and so on.

Volcanic ash has high permeability making some of these good recharge areas. Scoria and pyroclastic flow sediments have relatively high permeability; also the basaltic lava has many cracks that make them good recharge zones. Climatically, the areas receive much rainfall and have high water retention capacity. Despite being good recharge zones, the water levels are relatively very deep due to the very thick volcanic ash and pyroclastic sediments which has high permeability. Drilling depths is estimated to be 100-250 m.

4.2 Hydrogeology of Tanzania

The occurrence of groundwater is largely influenced by geological conditions. Hydrogeologically about 75% of Tanzania (Kongola *et al*., 1999) is underlain by crystalline basement complex rocks of variable composition and ages, but predominantly Precambrian, which form the basement aquifers (for example the Pangani and Makutopora basins). Other aquifer types include karroo (found in Tanga), coastal sedimentary formation of limestone and sandstone (e.g. Dar es Salaam), and the alluvial sedimentary sequence, which mostly include clay, silt, sand and gravel, and volcanic materials (e.g. Kahe -Pangani basin). The groundwater potential of each main aquifer type differs much from place to place or basin-wise due to variability in aquifer formations and recharge mechanisms.

Nevertheless, the hydrogeology of Tanzania has not been thoroughly studied and owing to that, the quantification of the groundwater resources of the country has not yet been possible because of lack of requisite data. In most cases, the only available information has been compiled from existing boreholes log data. However, some efforts have been done in assessing groundwater resources in Rufiji and Pangani River Basins, where systematic and basin-wise attempts to evaluate the groundwater resources potential have started (Kongola *et al*., 1999) and of recent the Internal Drainage Basin (JICA, 2008) and Wami Basin.

Baumann *et al*., (2005) provide a general overview of the stratigraphic sequence or the depth-wise variation from the analysis of broad classification of the aquifer formations and the geologic data of the boreholes. The general aquifer formations in Tanzania are summarised in Table 4.1 and Figure 4.2. Therefore, according to (Baumann *et al*., 2005), the following categorizations were revealed:

- In most regions and notably in Mtwara, Coast, Morogoro, Ruvuma, Shinyanga, Kilimanjaro, Kagera, Lindi, Mwanza and Mbeya the dominant water bearing formations are unconsolidated sand and gravels.
- In region such as Singida, Mara, Iringa, Kigoma, Dodoma, Rukwa and Manyara the water bearing formations are predominantly weathered and/or fractured

Granites/Gneisses. Arusha is dominated by igneous rocks and the water bearing zones are mostly in weathered and fractured lava flows.

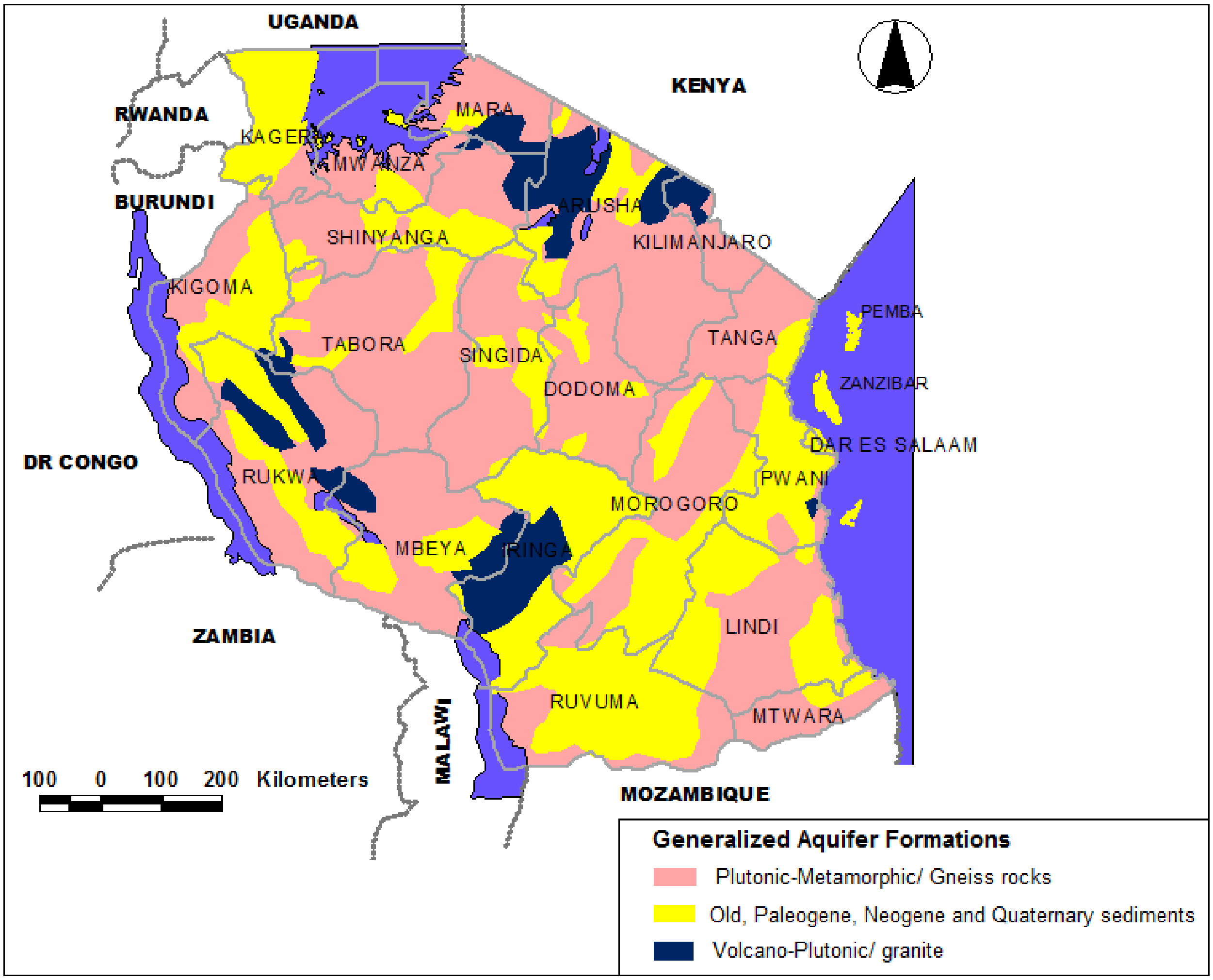
- In Tanga region, the semi-consolidated marine sediments and the Karoo sandstones are mostly the water bearing zones.

Table 4.1: Generalised aquifer formations and percentage area coverage in Tanzania

Category	Aquifer Type	Main lithologic units	Area (%)
1	Old, Paleogene, Neogene and Quaternary sediments	Alluvial: sand, gravel, silt, mud Lacustrine: sand, sit, limestone, tuff Terresterial: sand, gravel, laterite, silcrete, calcrete; Fluviatile: marine, sand, gravel, silt, limestone	20
2	Volcano-Plutonic/ granite	Black clay soil, yellow altered ash, white pumice and ash breccias, paleosoil with clay and volcanic rocks, alluvial deposits, sand with basalt, weathered basalt,	15
3	Plutonic-Metamorphic/ Gneiss rocks	Marble; quartize, graphitic schist, chlorite, amphibolite, mica and kyanite schist, hornblend biotite and garnet gneiss, acid gneiss, granulite, charnockite, magmatite; mudstone, shale and phylite, arkose, qartize, conglomerate, limestone	65

The Old, Paleogene, Neogene and Quaternary sediments are mostly unconsolidated and semi-consolidated where the old sediments occur. The Volcano-Plutonic are mostly consolidated and the Plutonic-Metamorphic are also consolidated except when weathered. Geological unit of quaternary formation exists throughout the area, mainly the coastal plain of Dar es Salaam. In the Quaternary formation, the groundwater has been developing very actively, accordingly the number of well are the highest. Almost 50% of the wells in the area are tapped from Quaternary aquifer. The yield of these well is generally high, especially in Dar es Salaam Region. Records indicate very high yield of more than 100 liters/min in average value. Neogene sediments consist of interbedded sandy clays and clayey sands with minor lenses of pure sand or clay. The gravel of mostly quartz is scattered throughout in a clay matrix. Since the formation is distributed extensively, large number of wells has been drilled into the Neogene aquifer. Neogene aquifer shows relatively higher yield with an average yield of about 24.5 liters/min.

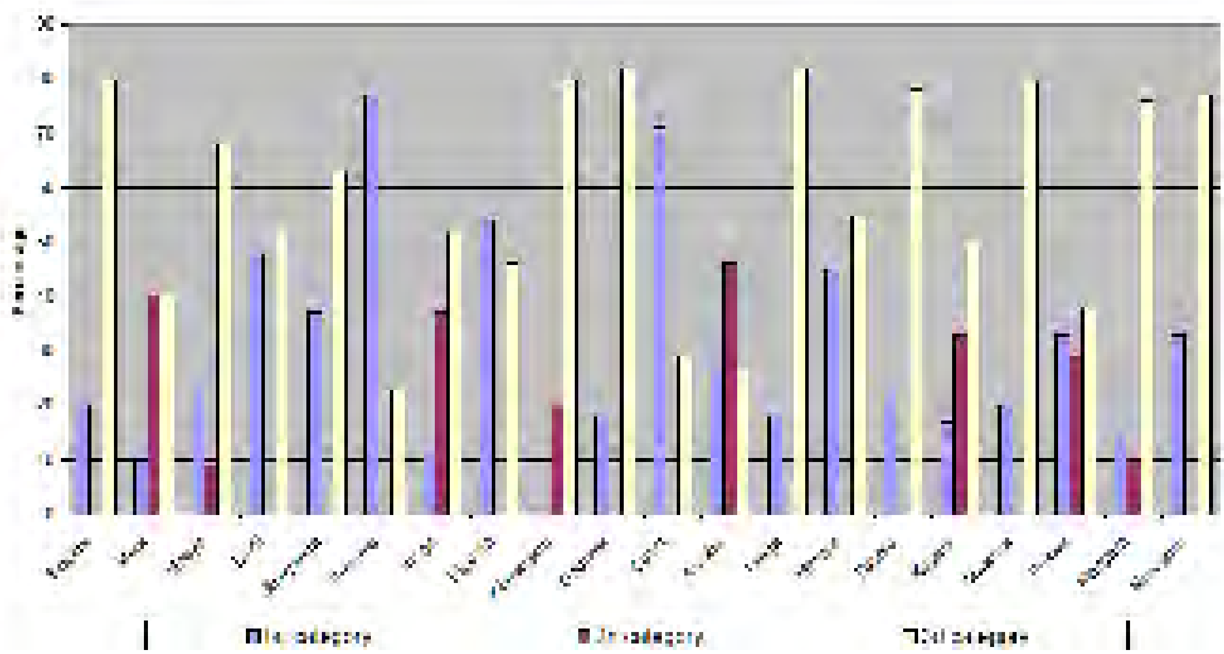
Boreholes drilled in the 1st and 2nd category (Table 4.1) are expected to be fairly homogenous depth-wise, mostly sediments in the first and volcanic and granites in the latter. In the 3rd category, typical sections usually include unconsolidated superficial deposits, weathered granites/gneiss, fractured granite/gneiss and solid bedrock. Figure 4.3 presents the distribution of aquifer categories by regions.



Source: Modified from Baumann *et al*., (2005)

Figure 4.2: Aquifer Formations

Where significant local deposits of sediments overlay the Plutonic-Metamorphic rocks, they constitute an isolated aquifr system. Therefore, while the generalised map could be used as a first approximation for an overall planning borehole, sitting remains a-case-by-case issue due to variations in aquifer formations.



Source: Baumann *et al*., (2005)
Figure 4.3: Distribution of Aquifers by Region in Tanzania

4.3 Aquifer properties

The water yielding properties of rocks, unconsolidated sediments and other deposits depend on the interstices and voids which exist within such formations (Coster, 1960). The quantitative information on aquifer characteristics and recharge rates, including groundwater flow regimes, abstraction rates and quality controls is very uneven and generally incomplete. However, few studies (e.g. Coster, 1960; Shindo, 1989; JICA, 2008) provide some information about the aquifer. The test pumping is usually carried out by airlift with a constant yield and variable drawdown. Precise estimates of the transmissivity and storage coefficients are not usually made. The test pumping merely gives an idea of the possible output of the well and the capacity of the pump; and when conducted, the test pumping is continued for a maximum of 24 hours. The limited pump test data available (e.g. Table 4.2, Table 4.3) indicate that the aquifers have range of transmissivity values from low to high values with hydraulic conductivity ranging from 1 md^{-1} to higher than 16 md^{-1} (Shindo, 1989 cited in Rwebugisa, 2008). The high variability in transmissivity values is attributable to the heterogeneity in aquifer system. Since transmissivity is controlled by hydraulic conductivity and aquifer thickness, the high transmissivity values in basement rocks are associated with faults (Foster, 1960).

Table 4.2: Aquifer parameters from 1988 pumping test analysis

BH ID	AQUIFER THICKNESS (m)	SWL (m)	YIELD (m^3hr^{-1})	DURATION (min)	SPECIFIC CAPACITY (m^2d^{-1})	TRANSMISSIVITY (m^2d^{-1})
88/75	41	26	16	840	1	93
97/75	32	26	52	840	8	841
169/75	57	23	79	840	10	671
170/75	85	22	28	840	3	490

Source: Shindo (1989)

Table 4.3: General aquifers information data (URT, 1989)

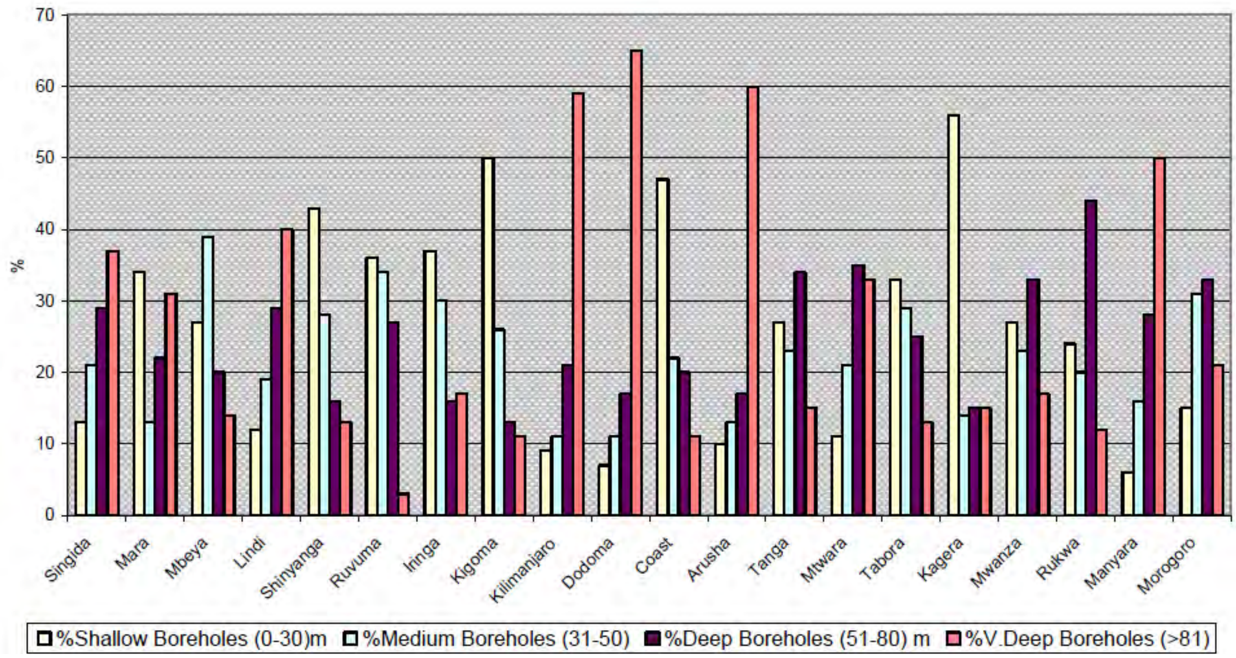
General data collected from water boreholes, for various formations

		In 25 to 75 % of cases			
Geological formation	Number of boreholes	Depth (m)	Specific yield (l/s/m)	Main aquifers	Comments on water quality
Precambrian P1a and P1b (part of the regions of Tabora, Dodoma, Iringa, Shinyanga, Arusha and Singida)	1,570	30-120	0.015-0.15	Altered crystalline rocks	Sweet to slightly brackish water, with high fluorine content in some cases
P2	50	90-120	0.25-5	Fractured granitic rocks	-
P3 and P5	205	70-95	0.01-0.25	Fissured zones of sandstones, argillaceous schists and granites	Sweet
P4 (In many places in regions of [illegible], [illegible], [illegible], [illegible], Kigoma and [illegible])	205	70-120	0.01-0.15	Altered zones and joints of crystalline rocks	Slightly brackish or saline
P4 ([illegible], [illegible], [illegible])	75	40-100	0.25-1.20	Fractured crystalline rocks	Sweet
Karroo at Tanga	22	30-60	0.15-0.5	Clastic formations	Sweet
Post-Karroo at Tanga, [illegible], [illegible]	50	40-70	0.01-0.15	Clastic formations	Occasionally brackish
Rungwe Tertiary volcanic rocks	50	40-100	0.12-0.16	Lavas and pyroclastics	Sweet
Tertiary volcanic rocks of Lower Moshi, [illegible], Arusha	40	40-150	1.5-6	Lavas and pyroclastics	Sweet with high fluorine content in some cases
Tertiary [illegible] sediments of [illegible], [illegible], [illegible], [illegible]	10	90-150	0.005-0.12	Contact zones of strata	Slightly brackish to saline, high fluorine content
Tertiary continental deposits of [illegible] and [illegible]	25	60-120	0.10-0.90	Sands, gravels	Slightly brackish to saline
[illegible] marine deposits of Tanga, Kibaha, Bagamoyo, Dar Es Salaam	150	40-85	0.005-5.0	Clastic rocks	Slightly brackish to saline
Neogene colluvium-alluvium of the valleys of [illegible], Kilombero, [illegible], [illegible], Rufiji	80	20-?0	0.25-3.0	[illegible] rocks	Sweet

Note:
P1a is a subgroup of Precambrian crystalline basement which dates 3,000 to 2,000 million years ago. It occupies most of the centre and north of the country
P2 is a subgroup of Precambrian crystalline basement that includes mineralized zones of crystalline granites and metasedimentary rocks ("Karagwean-Ankolean") near the north-west frontier with Burundi
P3 is a subgroup of Precambrian crystalline basement that dates to 1,000-700 million years ago and is called "Bukobian". It includes sedimentary formations (sandstones, dolomites, argillaceous sandstones) and volcanic rocks of basaltic typej it occupies the north-west of the country between Lakes Victoria and Tanganyika
P4 is a subgroup of Precambrian crystalline basement that includes the Ubendian, which is the oldest, and the Usangarian-Mozambiquan. The Ubendian runs north-west in the far south-west of the country. The Usangarian-Mozambiquan dates to 600 million years ago and runs north-east in the eastern part of the Tanzanian plateau, crossing into Kenya in the North-east and Malawi/Mozambique in the south. It consists of gneiss, schists, migmatites. amphibolites, charnockites and crystalline dolomitic limestones.

4.4 Boreholes classification in Tanzania

In the common phraseology, boreholes in Tanzania are classified as shallow (0-30m), medium (31-50m), deep (51-80m), and very deep (>80m) (Baumann *et al*., 2005). Figure 4.4 indicates the percentage of boreholes as per each class Region-wise.



Source: Baumann *et al*., (2005),

Figure 4.4: Borehole Depth Distribution by Region in Tanzania

The above classifications represent the groundwater conditions of the regions. The number of boreholes to be drilled, the aquifer distribution, and the borehole depth distribution can indicate the type of technology to be used in the different regions.

4.5 Boreholes and dug well potential

Baumann *et al*., (2005) analysed the boreholes database described in section 4.4 to corroborate the groundwater condition. The analysis revealed that in areas where the static water level is less than 8 meters, shallow hand dug well fitted with hand pumps was feasible. Furthermore, analysis of the static water levels revealed a high percentage possibility of dug wells (Table 4.4). Kongola *et al*., (1999) provided a summary on distribution of recorded boreholes basin-wise (Table 4.5). Generally, most boreholes are located in the internal drainage basin. The basin is characterized by semi-arid to arid conditions with rainfall less that 550mm annually, making the dwellers dependent mostly on groundwater as the main source for water supply.

Table 4.4: Suitability for Dug wells based on depth of static water level

Regions	Percentage range of sites suitable for dug wells
Ruvuma, Dodoma, Arusha, Manyara	20-30
Tanga	31-40
Singida, Mara, Iringa, Kigoma, Kilimanjaro	41-50
Shinyanga, Coast, Morogoro	51-60
Mbeya, Mtwara, Kagera, Mwanza, Rukwa	60-70

Source: Baumann *et al*., (2005)

Table 4.5: Drainage basins and distribution of recorded boreholes in Tanzania

Name of basin	Number of boreholes drilled	Boreholes with high yield (more than 900 l/h)
Pangani	325	292
Ruvu/Wami	892	522
Rufiji	440	268
Southern Coast/ Ruvuma	344	188
Inland Drainage	1595	562
Lake Victoria	773	316
Lake Tanganyika	380	132
Lake Rukwa	263	128
Lake Nyasa	63	4

Source: Kongola *et al.,* (1999).

5.0 PATTERNS OF GROUNDWATER USE AND AQUIFER RECHARGE

5.1 Groundwater use for domestic services and industries

Groundwater development has concentrated mainly on shallow wells for domestic purposes over a wide part of the country (mainly rural areas). It is preferred for domestic water supply in rural areas because it easy and cheap to develop as compared to surface water and it can be developed where it is required. Furthermore, it is associated with low operation and maintenance costs and not much affected by drought unlike surface water resources. Owing to that, it is commonly used in the peri-urban fringes where there is no distribution network and places with unreliable supply. In Tanzania, groundwater is an important water source supplying more than 25 % of the domestic water consumption (JICA, 2002). Groundwater is the main source of water for most rural water systems and municipalities like Dodoma, Arusha, Shinyanga, Moshi and Singida, and of recent Dar es Salaam City. Many other urban areas exploit groundwater to augment supply from surface water sources (Figure 5.1). The boreholes are mainly found in urban settings, some are over 100 m deep. Throughout the country shallow wells are used for domestic water supply, i.e. hand-dug wells and improved wells. The borehole database maintained by the MoWI records 9,242 boreholes as of 2005 (Baumann *et al*., 2005). However, the National Rural Water Supply and Sanitation Programme (NRWSSP) aim to provide access to safe water to an additional 14.5 million people by 2015 at a cost of USD 533 million. This provides a substantial market for drilling of about 1,600 boreholes annually (Baumann *et al*., 2005). The existing borehole record indicates that in town; about 1,000 boreholes (registered and not registered) are drilled each year. About 9,000 boreholes extract 50,000 to 70,000 $m^3 day^{-1}$ from the aquifer. This excessive use may cause salt-water intrusion and damage to the aquifer.

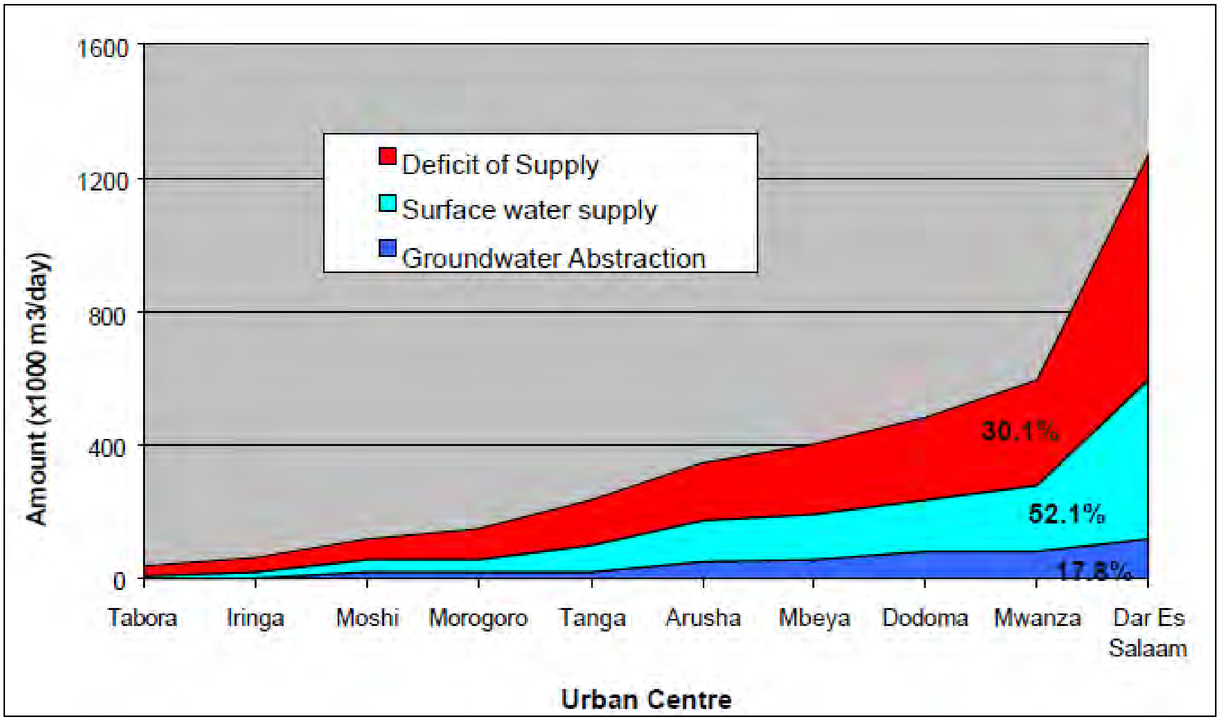
Domestic supply (both urban and rural) is a largest user of groundwater and consumes 755,000 $m^3 day^{-1}$ (60% of total use) against demand of 0.8 to 3.4 MCM day^{-1} (Kongola, 2008; DWR, 2010). Irrigation for sugarcane, flowers, vegetables and fruits such as grapes consumes 130,000 $m^3 day^{-1}$ (10%) while mining and industrial use consume about 30,000 $m^3 day^{-1}$ (2%) (Table 5.1). Livestock and others such as dry land fishing use about 350,000 $m^3 day^{-1}$ (28%). The total groundwater use is about 1.265 MCM day^{-1}which is about 12% of available groundwater resources (11 MCM day^{-1}).

Table 5.1: Estimates of groundwater use in Tanzania (DWR, 2010)

Sector	Amount used per day (m^3)	% of total use
Urban	130,000	10
Rural	625,000	50
Agriculture	130,000	10
Industrial and mining	30,000	2
Others (livestock, dry land fishing)	350,000	28
Total	**1,265,000**	**100**

Source: http://xa.yimg.com/kq/groups/22477246/889666431/name/Aquifer+characteristics.pdf

Groundwater utilization for industrial use is more concentrated in urban areas, especially Dar es Salaam where about 80% of the industries are located. Due to inadequate water supplies many industries have opted for constructing private wells to augment surface water supply. Industries in Dar es Salaam, like Tanzania Breweries Ltd. (TBL), Tanzania Cigarette Company (TCC), Friendship Textile (Urafiki), Ubungo Farm Implements (UFI), Kibuku, Mpishi, and Tanzania Portland Cement factory (TPC - Wazo Hill) etc, have private wells (Mato *et al*., 1998, Drilling and Dam Construction Agency, 2001). The list is rapidly increasing and similar trends are observed in Arusha municipality.



Source: Mato, 2002

Figure 5.1: The role of groundwater resource in major urban areas in Tanzania

5.2 Groundwater Use for Irrigation

Groundwater is a viable source of irrigation for many areas in the country. In other places which have persistent water shortages such as Shinyanga, Coast, Mwanza, Arusha, Mara, Tabora, Dodoma, Singida, Mtwara and Lindi Regions, it is a better and secure alternative to surface water (URT, 2002). Groundwater use for irrigation is estimated at about 130,000 m^3day^{-1} (Kongola, 2008). About 88% of groundwater extracted from the Pangani river basin is used for irrigation, 4% for industrial use and 8% for domestic use (Mato, 2002). Groundwater is currently being used for irrigation purposes in sugarcane, paddy, horticulture, vegetable and flower farming (e.g. Tanzania Planting Company, TPC-Moshi (over 7800 ha), and sugarcane plantation and Kilombero sugar estates) (Mato, 2002; *Interviews with Eng. Omary Zonal Irrigation Engineer, Moshi*). Sophisticated sprinkler systems are being used in sugarcane plantations while drip irrigation systems are mostly used to irrigate horticulture and flowers. The area irrigated varies considerably depending on the technologies uses to lift water and the financial capability. For example, small scale farmers normally use low cost technologies (e.g. concrete pedal pumps and treadle pump) to lift water from shallow groundwater wells (up to 10 m) (FAO, 2007).

According to (URT, 2002; Baumann *et al*., 2005), regions most prospective for groundwater irrigation include:

- Mtwara, Coast, Morogoro, Ruvuma, Shinyanga, Kilimanjaro, Kagera, Lindi, Mwanza and Mbeya due to the dominance of unconsolidated sand and gravels water bearing formations that permits good yields and the existence of suitable soil for agricultural crop cultivation.

- Singida, Mara, Iringa, Kigoma, Dodoma, Rukwa and Manyara due to predominance of the weathered and/or fractured Granites/Gneisses water bearing formations, including Arusha which is dominated by igneous rocks and the water bearing zones are mostly in weathered and fractured lava flows with suitable land for crop cultivation.

5.3 Estimation of groundwater irrigation potential

According to JICA (2002), the gross potential irrigation area is estimated at 2.1 million ha. The estimated existing irrigation area by inventory survey is 854,300 ha, which indicates that there would still be plenty of room for further irrigation development in the country. Nevertheless, detailed analysis on groundwater irrigation potential nation-wide has not been thoroughly explored. Additionally, the present situation of groundwater use for irrigation has not been studied, making it difficult in estimating the proportion of the land under groundwater irrigation in Tanzania. Most of the estimates are based on surface water information. Therefore, there is a need for a more comprehensive assessment of available groundwater resources and establishing the groundwater potential for irrigation in Tanzania.

5.4 Livestock watering

In arid and semi-arid rural areas of Tanzania (e.g. Dodoma, Singida, Shinyanga, Mwanza, Tabora) livestock watering using groundwater is very common. These areas have limited surface water resources and receive rainfall averaging less than 550 mm annually. There are few boreholes and the majority depend on shallow wells (mostly hand dug wells) for the watering of livestock. The lifting of water from the wells is done using a bucket fitted with a rope and poured on the water trough for livestock watering. Nonetheless, the effort of lifting the water is regarded as less effort than moving elsewhere with the livestock for a surface source and owing to that groundwater has always been considered a secondary priority. At the moment, there is no exact information on the amount of groundwater used for livestock, but considering the number of livestock in the country it is imperative that the amount consumed established.

Presently, there is ongoing development of water sources for livestock use which is being facilitated through DADPS and other projects such as PADEP, DASIP, TASAF and the Ministry of Water and Irrigation.

5.5 Groundwater recharge

Groundwater recharge is controlled by various factors including climate, geomorphology and geology (Rwebugisa, 2008). In most areas of Tanzania, the recharge occurs in topographic high areas mostly by direct rainwater infiltration, preferential flows and through fractures. Most recharge areas include alluvial fans with coarsely grained sands, where enhanced high infiltration rate occur. In fractured rocks, flow is often localized in a few main flow paths that control most of the hydrological response of the aquifer (Borgne *et al.*, 2007). Presence of termite mounds (as observed in the Makutapora groundwater basin) in the pediment area and on the upland slopes adjacent to the fault systems acting as preferential flows of rainwater to infiltrate to the subsurface, enhance recharge (Shindo, 1989). Nevertheless, there are limited extensive studies on recharge in Tanzania. Few detailed studies have been conducted (e.g. Shindo, 1989, 1990, 1991 in Makutapora groundwater basin; Mjemah, 2008 in quaternary sand aquifer in Dar es Salaam; Sandstrom, 1995 in Babati District, and JICA, 2002 in Internal Drainage Basin).

The estimated recharge flux (Shindo, 1989, 1990, 1991; Kashaigili *et al*., 2003; Rwebugisa, 2008) in the basin range from 5 to 10 mm $year^{-1}$, averaging to 1.3% of the annual rainfall. However, the area of the basin is just a fraction of the Tanzania mainland and owing to that the recharge rates are not applicable country-wide. A study by (Mjemah, 2008) in quaternary sand aquifer in Dar es Salaam indicate that groundwater recharge range between 0 and 570 mm $year^{-1}$ depending on the rainfall amount in that particular year. The average aquifer recharge for the period1971 to 2006 is estimated at 240.7 mm $year^{-1}$. Foster (1960) estimated 10 percent groundwater recharge in many areas to be the maximum that can be expected, but that in other localities the percentage recharge may well fall to 4 percent or even below. A study by Sandstrom (1995) in Babati District indicate that in the wet year, almost all rainfall events generate recharge, *i.e.* the lightest rainfall events, representing 50% of annual total, also provided about 50% of all recharge. In the dry year, however, an imbalance developed, *i.e.* the same portion of the rainfall events provided only about 25% of the recharge.

JICA (2002) based upon hydrological information through a water balance analysis tried to estimate the basin groundwater recharge and basin evapo-transpiration at the river basin scale across the country. The findings of the study are summarized in Table 5.2. The total ground water recharge on annual basis is estimated at 3,725 MCM (0.4 %) (JICA, 2002). A general outlook on the various recharge estimates indicate that the values are greatly variable location-wise and are a function of the methods used. The estimated basin recharge (JICA, 2002) rates are very low and contain a great deal of uncertainty, implicating on groundwater development potential. Therefore, more detailed studies on groundwater recharge are imperative.

Table 5.2: Estimated recharge from hydrological Balance by River Basin

No.	Drainage River Baisins	Catchment Area (sq.km2)	Inflow	Outflow			Remarks
			Annual Mean Rainfall* (mm)	Annual Mean Runoff* (mm)	Evapo-transpiration from the Basin** (mm)	Groundwater Recharge*** (mm)	
I	Pangani River basin	56,300	1,001.9	31.5	966	4.0	into the Indian Ocean drainage system
II	Ruvu/Wami River Basin	72,930	765.1	51.7	710	3.0	into the Indian Ocean drainage system
III	Rufiji River Basin	177,420	988.3	185.9	799	3.0	into the Indian Ocean drainage system
IV	Ruvuma River and Southern Coast Basin	103,720	1,050.0	20.5	1,028	2.0	into the Indian Ocean drainage system
V	Lake Nyasa Basin	39,520	1,672.5	344.6	1,324	4.0	into the Lake Rukwa drainage system
VI	Internal Drainage Basin	153,800	619.0	36.6	577	5.0	into the Internal drainage system
VII	Lake Rukwa Basin	88,180	1,095.0	104.5	985	6.0	into the Lake Rukwa drainage system
VIII	Lake Tanganyika Basin	151,900	1,173.6	124.7	1,045	4.0	into the Atlantic Ocean drainage system
IX	Lake Victoria Basin	79,570	1,111.1	18.6	1,087	6.0	into the Mediterranean Sea drainage system
	Total	923,340	997.5	97.0	896	4.0	

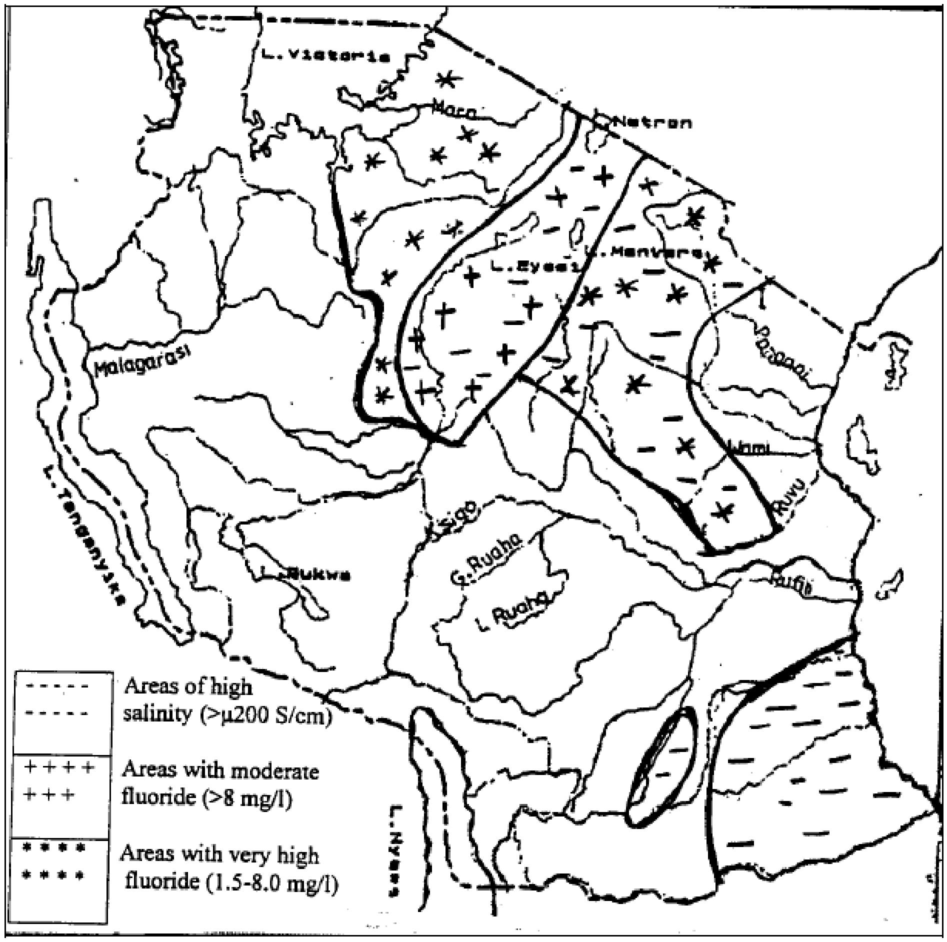
** : These were analyzed using data of 143 gauging stations.*

*** : These were estimated deducting (Runoff) and (Groundwater recharge) from (Rainfall).*
**** : These were tentatively estimated consulting the groundwater potential map in "RAPID WATER RESOURCES ASSESSMENT, 1995".*
Source: JICA, 2002.

5.6 Groundwater quality in Tanzania

Groundwater quality is controlled largely by geology and the groundwater quality in terms of salinity and fluoride in Tanzania is presented in Figure 5.2. Groundwater in the Rift zone of the north are typically alkaline and soft (low calcium and magnesium concentrations) with high pH values and relatively high sodium concentrations. Some are saline, although groundwater around the extinct volcano, Mount Meru, is reported to be generally fresh (total-dissolved solids usually less than 1000 mgl^{-1} (Issar, 1978).

Groundwater from the ancient crystalline basement of central Tanzania also typically have high alkalinity and relatively high sodium concentrations and with slightly acidic to highly alkaline pH values 6.1 to 9.1 (Nkotagu, 1996). Salinities vary but can be high with total-dissolved solids between 1000 and 3000 mgl^{-1}. The high concentration of chloride (salinity) in groundwater is the main problem especially in the coastal and central regions of the country (like Singida, Shinyanga, Lindi and Mtwara), where there is a high evaporation rate and poor drainage. Groundwater from the recent sediments in the coastal plain is vulnerable to marine intrusion, particularly where groundwater-pumping rates are high. Evidence of marine intrusion has been found in the coastal aquifer of the Kigamboni Peninsula (Dar Es Salaam) with elevated chloride, sulphate and sodium concentrations and with total-dissolved solids up to 1700 mgl^{-1} (Nkotagu, 1989). In Lindi and Mtwara regions, high carbon dioxide in groundwater has been reported (Kongola *et al*., 1999), which causes groundwater to be corrosive.



Source: Rweyemamu, 1999 cited in Mato, 2002

Figure 5.2: General groundwater quality in Tanzania

High iron content in groundwater has been observed in Mtwara and Kagera regions (Kongola *et al*., 1999). Nitrate levels of more than 100 mgl^{-1} have been reported in the Makutopora basin, Dodoma and Singida town (Nkotagu, 1996; Kongola *et al*., 1999). Little information is available for groundwater quality in the sedimentary aquifers from the south eastern part of Tanzania.

In groundwater from both the volcanic terrains and crystalline basement rocks in the central plateau, fluoride concentrations are known to be high and consequently far more information is available for fluoride than for other trace elements of health significance. Of the reported groundwater-quality problems in Tanzania, fluoride is by far the most severe and widespread (Mato *et al*., 2000; Materu, 1996). It represents a major problem for water supply nationally. The problem occurs in both the Rift zones in northern and south-western Tanzania, associated with volcanic activity, and in the crystalline basement complex of the central plateau. Concentrations as high as several tens to hundreds of milligrams per litre have been reported for some groundwater and high concentrations have also been found in some rivers, soda lakes and hot springs in the Rift zones.

Table 5.3: Fluoride Concentration in Tanzania

Region	Site	Concentration (mgl^{-1})	Source of information
Northern Tanzania	Rivers Springs Alkaline lakes:	12 to 26 15 to 63 60 to 690	Nanyaro *et al*. (1984)
Shinyanga/Tabora - Isanga Basin;	Seke Wembere Depression	21 to 250 7 to 40	Bugaisa (1971)
Dodoma/Singida	Bahi depression Kongwa Kondoa	up to 180 up to 90 4-7, up to 80	Bugaisa (1971)
Arusha/Kilimanjaro	Sanya Corridor Ngorogoro Crater and Lemagrut volcanic cone; Serengeti Ol Balbal Depression Mbulu District Lake Natron Basin	up to 170; (4-8 further north) up to 150 over 86 up to 99 up to 330	Bugaisa (1971)
Mbeya region	Rukwa Depression	up to 75	Bugaisa (1971)

Such concentrations are extremely high, even when compared to other high-fluoride groundwater provinces elsewhere in the world. Incidence of dental fluorosis is very high in these affected areas, and skeletal fluorosis is also serious in parts. Severe cases have been reported in Kitefu village, east of Arusha (Nanyaro *et al*., 1984).

Fluorine-rich minerals are abundant in the lavas, intrusions and ashes of the Rift zone, and concentrations are much higher than in similar rock types elsewhere in the world (Kilham and Hecky, 1973). In addition, fine-grained ash deposits present in the Rift are readily leachable. Hot springs are also important sources and account for some of the most extreme concentrations observed in the groundwater of the northern Rift zone. Some concentration of fluoride in groundwater from the major depressions also appears to have occurred through extreme evaporation of lake water and subsequent infiltration to the shallow aquifers.

Fluoride build-up in groundwater from the crystalline basement of the central plateau derives by dissolution of fluorine minerals (e.g. fluorite, apatite) and is facilitated by relatively low dissolved calcium concentrations. Concentrations in groundwater from the coastal plain appear to be low. Nkotagu (1989) quoted values in the range 0.002 to 0.38 mg/l.

Nitrate concentrations have been reported affecting groundwater quality in some areas of Tanzania (e.g. Shindo, 1990, 1991). However, the distribution of nitrate in groundwater nationally is not known. High concentrations (0.002 mg/l to 102 mg/l as N, mean value 34 mg/l) have been reported in both shallow and deep groundwater in the Dodoma area of central Tanzania (Nkotagu, 1996 a,b). High values were linked to pollution from sewage effluents in urban areas, with penetration of the pollution to deep levels in the crystalline aquifer via fractures.

Apart from geological control on the groundwater quality, there is also the influence of human activities on the natural quality of groundwater resources (Mato, 2002). The situation is more alarming in urban areas, which are growing at a fairly fast rate. The potential sources of groundwater pollution include domestic and industrial wastewater, leaching of leachate from solid waste dumpsites and mining tailings, storm water and poor agricultural practices (Mato, 2002).

6.0 COST OF GROUNDWATER DEVELOPMENT IN TANZANIA

6.1 Drilling industry in Tanzania – an overview

In the past, drilling was done by the government through the regional offices of the Ministry responsible for water and private sector participation had been minimal. This approach created a government owned drilling fleet. The rigs were typically purchased under projects and often used by foreign contractors. At the end of the projects period, they were handed to the ministry (Baumann *et al*., 2005).

To centralise the regional drilling capacity, a public agency - Drilling and Dam Construction Agency (DDCA) was established under the Executive Agencies Act No. 30 of 1997. The agency was formed to develop safe and sustainable water sources through drilling of deep and shallow wells and construction of surface dams for domestic use, irrigation, industrial use, etc. DDCA operates in the whole country; the agency is the largest drilling contractor in Tanzania. It provides services such as groundwater prospecting, drilling, construction of dams, on a commercial basis. As a government agency, DDCA suffers from the inefficiencies inherent to the public sector; low utilization of equipment due to disrepair and lack of supplies. Despite these setbacks DDCA remained the big player in the drilling sector. Lately, under the drive for structural reform and re-focus of the public sector DDCA was excluded from competing for World Bank financed drilling contracts. The National Water Policy (NAWAPO) (URT, 2002), states that in future the provision of services has to be done mostly by private operators. Establishing a thriving drilling industry has been complicated by the small size of the market relying mostly on public contracts. Private operators were reluctant to reach out to isolated rural areas where risks and costs are high (Baumann *et al*., 2005).

Sector-Wide Approach (SWAP), decentralisation, and community driven principles have been adopted in the NAWAPO (Baumann *et al*., 2005). These approaches bring the risk of fragmenting the market with inherent higher cost. They need to be reconciled with the requirement to plan drilling campaigns, which offer economies of scale by packaging sufficient number of boreholes. Consultant driven implementation often leads to over specified boreholes requiring expensive sitting, drilling, and development techniques (Baumann *et al*., 2005).

Drilling costs account typically for 80 % of the hardware investment costs for boreholes, the rest consisting of the hand pump and the apron (Baumann *et al*., 2005). The potential for cost saving in drilling is tremendous, the stakes are considerable; an average cost reduction of more than 10% is easily realistic, which, if realised, would result in savings of USD 10 million (Baumann *et al*., 2005). In order to achieve these savings it will be necessary to create a favourable environment for the private sector drilling industry to grow and invest in equipment and human skills. The public sector needs to be structured to make use of the opportunities the emerging market offers. Factors like productivity and costs for obtaining contracts have a bigger impact on drilling cost than diameter of wells and yield criteria. The young emerging drilling industry needs a steady stream of smaller contracts and mechanisms are required to help local drillers entering into the market. However, that does not mean that the saving potential lying in technology should be neglected; smaller diameter boreholes require smaller rigs, realistic acceptance criteria help to bring cost down for well development and sitting. Low-cost drilling technologies provide a significant potential for helping the local drilling industry being established. The investment costs are clearly less and the price per borehole can be reduced. The issue is not to develop new technologies but to transfer and adapt existing ones (Baumann *et al*., 2005).

The status of the drilling industry will have to be considerably strengthened to cope with the demand foreseen in the NRWSSP that aims to meet the MDG. According to Baumann *et al*., (2005) the Ministry of Water and Irrigation has issued three circulars (guidelines), which outlines the basic requirements in groundwater:

- Guidelines on procedures for groundwater exploration in Tanzania mainland
- Government regulations and guidelines on groundwater exploration in Tanzania mainland
- Government specifications and regulations applicable to water well drilling and installation in Tanzania mainland.

All firms interested in drilling have to apply for a "Permit for Water Well Drilling and Installation" from the Assistant Director, Hydrogeology Section, Water Resources Division. A list of equipment, drill rigs and accessories as well as CV's of personnel should be attached to the application. Officers from the Water Resources Division should physically inspect and scrutinize the listed items. Nevertheless, the procedures are not strictly followed (Baumann *et al*., 2005).

6.2 Borehole drilling trends in Tanzania

Boreholes have been constructed in Tanzania since at least 1930 up until the present day. The borehole database maintained by the Ministry of Water and Irrigation (MoWI) Directorate of Water Resources in Dodoma lists 9,242 boreholes as of year 2003. The data entry is not consistent; many boreholes have no data recorded and for others the data are incomplete. It is therefore difficult to establish how many of these boreholes are actually used to provide water. It appears that the shallow boreholes drilled by hand drilling methods were not recorded or only partially recorded. The Figure 6.1 gives the numbers of boreholes that were recorded in Dodoma national groundwater database over the last 25 years.

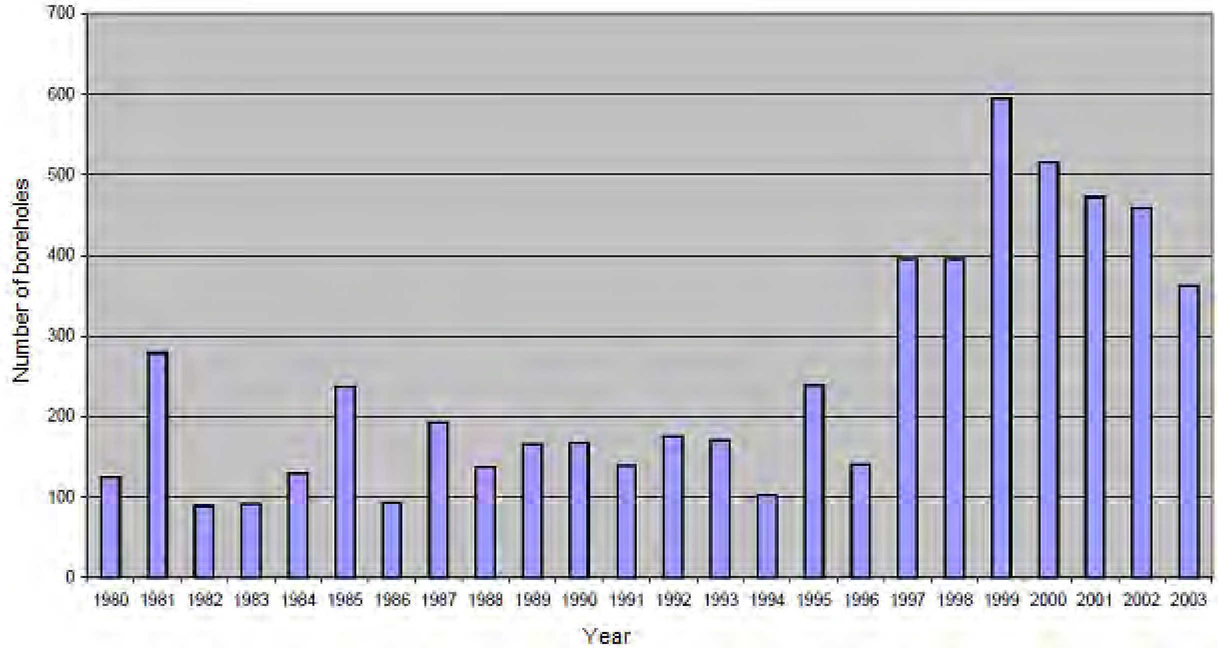


Figure 6.1: Boreholes drilled in Tanzania

The Potential Market

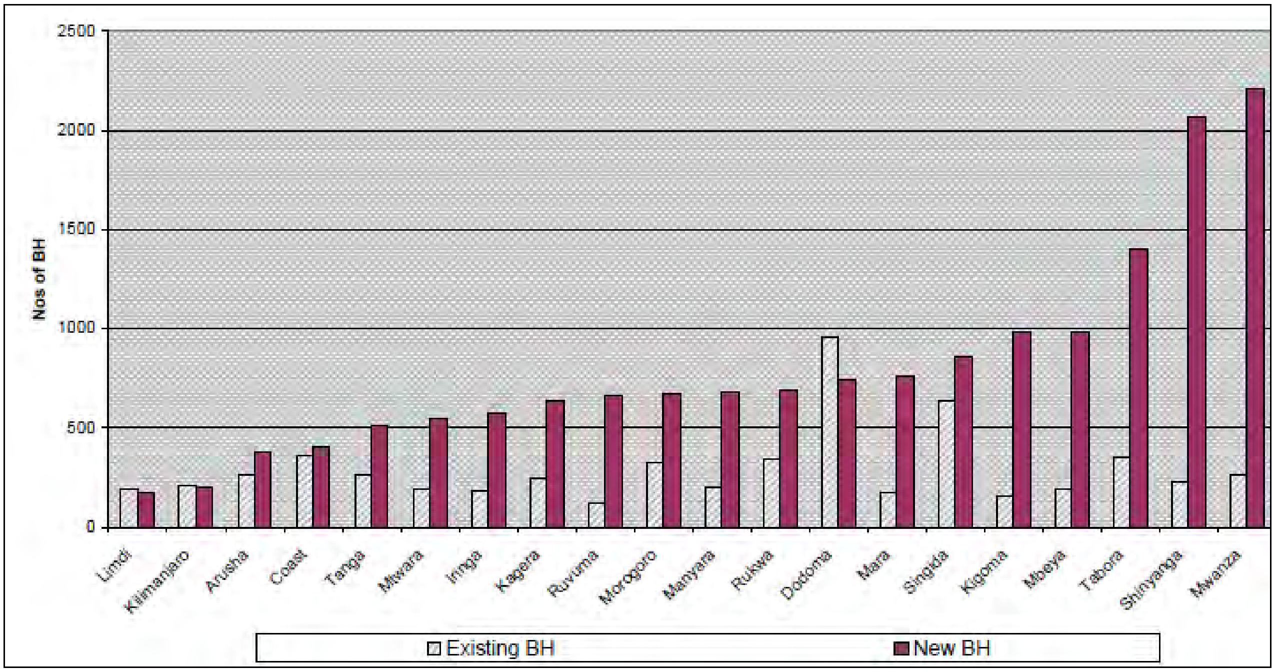
Tanzania has a high potential for groundwater development on the basis of aquifer characteristics, recharge and rainfall. Boreholes drilled for domestic water supplies indicate variable yields. The average static water level of productive boreholes is about 17 metres and the average total depth 62 metres (Baumann *et al*., 2005). The scope of the drilling market in Tanzania can be projected to include domestic water supply, industrial use, irrigation, recreational use, etc. However, domestic water supply remains the single most important market (Baumann *et al*., 2005).

Improved drinking water sources are considered to be all piped water, protected wells, boreholes/tube wells, medium/shallow wells equipped with hand pumps, and covered springs. On this basis, the overall percentage of households using improved water in 2000/2001 was found to be 56% (46% in rural areas and 88% in the urban). This overall coverage was observed to have risen 10% from 46% in 1991. To meet the Millennium Development Goals (MDG) the NRWSSP aims to provide access to safe water for 74% of the rural population by mid-2015. This implies an increase in water supply coverage to an additional 14.5 million people by 2015 at a cost of USD 533 million (NRWSSP, 2004). Obviously, this provides a substantial market for drilling in Tanzania. Under the assumption that 30% of the shallow wells for hand pumps are machine drilled, the investment plan estimates that the following numbers of machined drilled boreholes are needed until 2015 in the various regions (Table 6.1, Figure 6.2).

Table 6.1: Boreholes in NRWSSP per region

Region	Handpump & Shallow Well	Handpump & Borehole	Electric / Diesel Pumped & Piped System	Windmills	Total BH
Dodoma	32	399	84	226	741
Arusha	120	175	87	0	382
Kilimanjaro	53	126	18	0	197
Tanga	130	259	59	62	510
Morogoro	249	360	66	0	675
Coast	262	101	39	0	402
Lindi	45	39	85	0	169
Mtwara	146	362	37	0	545
Ruvuma	73	533	61	0	667
Iringa	15	543	13	0	571
Mbeya	131	767	88	0	986
Singida	169	483	50	155	857
Tabora	434	822	143	0	1399
Rukwa	80	567	43	0	690
Kigoma	129	790	63	0	982
Shinyanga	862	1008	167	32	2069
Kagera	525	0	108	0	633
Mwanza	960	1142	106	0	2208
Mara	310	379	75	0	764
Manyara	146	426	105	0	677
Total Tanzania	**4,871**	**9,281**	**1,497**	**475**	**16,124**

Source: Baumann *et al*., 2005



Source: Baumann *et al*., 2005

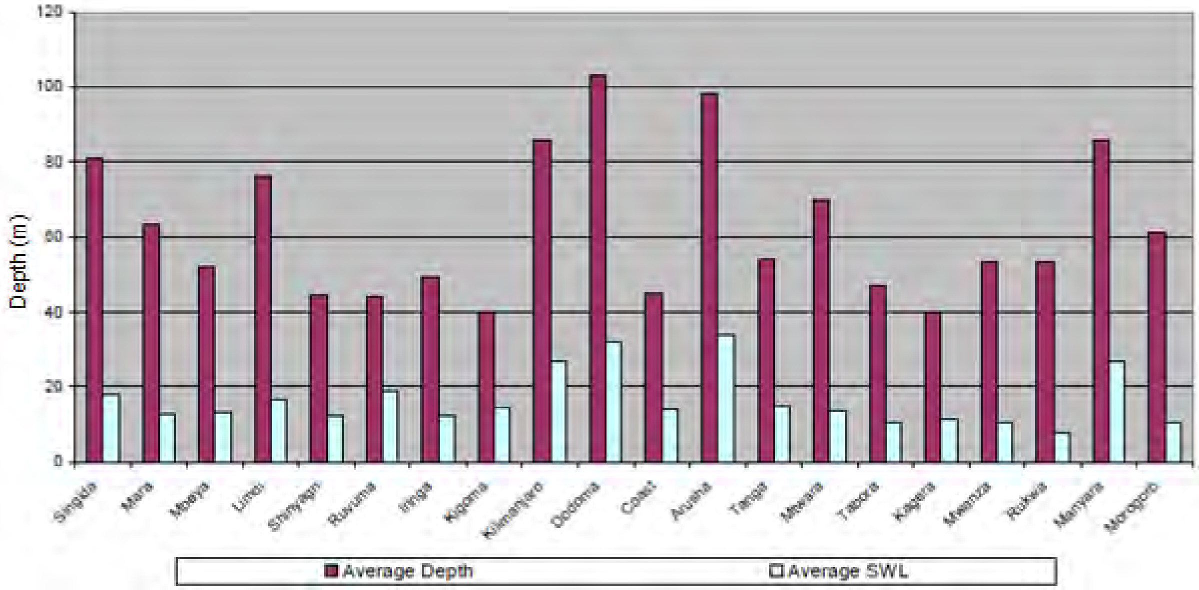
Figure 6.2: Borehole market (Calculated for drinking water only)

In the next 10 years, about 1,600 boreholes have to be drilled in rural Tanzania annually. Presently, the drilling industry produces about 900 licensed boreholes in rural areas. The capacity needs to be doubled to meet the targets set by the NRWSSP (Baumann *et al*., 2005).

6.3 Drilling depth and yield

Out of 850 holes drilled by DDCA in all of Tanzania during a period of 20 months (DDCA Database, 2003-2004 and 2004-2005), the deepest hole (dry) was 150m in depth. Only 26 boreholes were drilled deeper than 100m and a total of 50 boreholes were deeper than 80m.

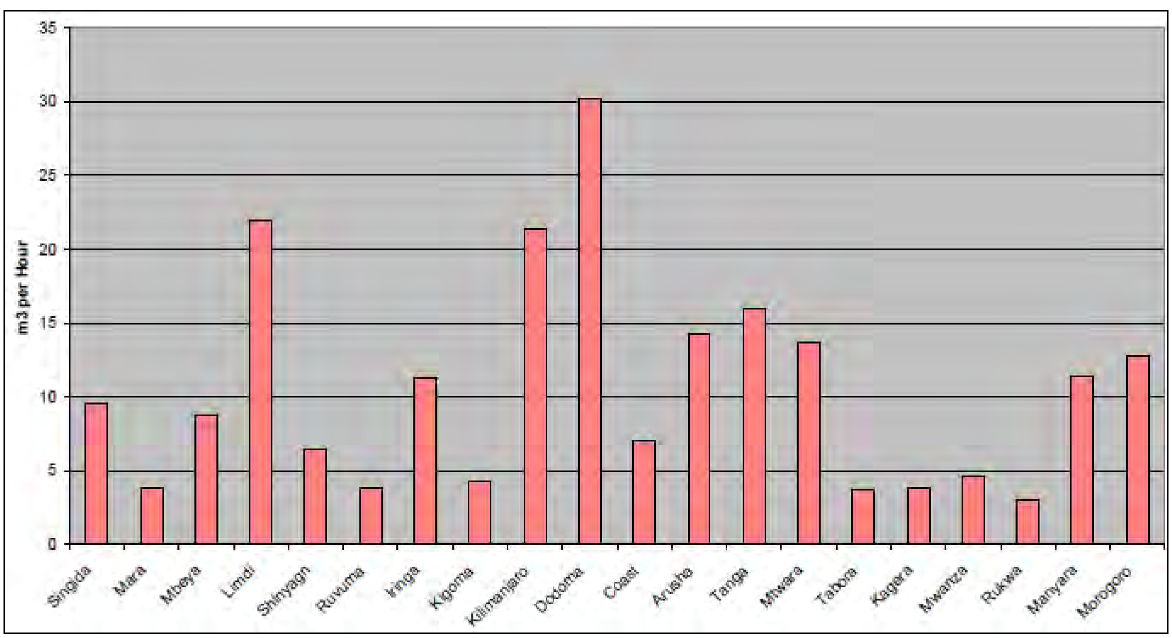
The available data in the Dodoma Borehole database covering 5,848 boreholes provided the means for estimating the depth and yield region-wise. This basic information can be combined with the regional geology to provide an idea of the drilling depth, type of formation and the expected yield. These factors have a direct bearing on the drilling technology to be employed and on the cost implications (Baumann *et al*., 2005). The Figure 6.3 and 6.4 present the average depths and yield respectively.



Source: Baumann *et al*., 2005

Figure 6.3: Borehole properties by Region

The average depth of all boreholes drilled in the 20 regions is 62.3m. The average static water level of all boreholes drilled in the 20 regions is 16.5m. The average yield of all boreholes is $10.6m^3$ hr^{-1}. It should be noted that a handpump requires a yield of $0.5m^3$ hr^{-1}. According to Sadiki (2009), yield of boreholes in Pangani Basin range between 10 and 800 m^3hr^{-1}. Depth of boreholes range between 20 and 200m and the major aquifers are indiscrete: (alluvial sediments - 10%, sedimentary – 4%, volcanic – 1% and metamorphic rocks – 85%). In Makutapora groundwater basin, some boreholes have yields of about $460m^3hr^{-1}$, while in Pangani basin, the yield of boreholes in Pangani Basin range between 10 and 800 m^3hr^{-1} (Sadiki, 2009).



Source: Baumann *et al*., 2005

Figure 6.4: Yield by region in Mainland Tanzania

6.4 Drilling Contracts and Cost

Analysis of tender documents for the Rural Water Supply and Sanitation Program (RWSSP by Baumann *et al*., (2005) highlighted a number of issues as regard to cost of drilling. Firstly, drilling work was tendered without pre-qualification of bidders. The tender evaluation did not dedicate sufficient importance to full and comprehensive information about the capabilities of the bidders and it did not reveal considerable inconsistencies. Secondly, the costs were high (considerably higher than the estimated unit costs). The following aspects have a positive impact on cost: a) Productivity, depreciation of equipment is a large cost factor, b) Procurement, economies of scale and packaging, and c) Low cost technologies, optimising well design and reducing borehole diameter (Baumann *et al*., 2005). However, cost considerations are not the only aspects. Quality and sustainability of works need to be taken into account as well. The challenge will be to strive for low cost without jeopardising quality.

6.5 Cost of Borehole Drilling and Water sampling

The cost for boreholes in Tanzania is about USD 6,000 for handpumps and USD 12,000 for mechanised systems (Baumann *et al*., 2005). The review of tender documents revealed that there are inconsistencies in costs from different bidders. An example of the tender analysis is provided by Baumann *et al*. (2005) and summarised in Table 6.2. The cost per meter was USD 193.29 in Mpwapwa (Hard rock) for borehole with depths up to 70m, USD 133.57 in Rufiji for boreholes with depths up to 100m (Sedimentary) and USD 99.98 in Rufiji for boreholes up to 50 m (Sedimentary).

Table 6.2: Review bids from RWSSP

Bidder	A			B			C		
Type of BH	3BH ~70m			3BH ~100m			15BH ~50m		
	Hard Rock			Sedimentary			Sedimentary		
District	Mpwapwa			Rufiji			Rufiji		
Cost Components		per BH	%		per BH			per BH	
Bid cost and overheads	2,640	880	7.2%	1,891	630	4.7%	4,629	309	6.2%
Mobilisation	3,000	1,000	8.2%	1,450	483	3.6%	3,550	237	4.7%
Transport between Sites	648	216	1.8%	1,189	396	3.0%	2,911	194	3.9%
Setting up on Site	600	200	1.6%	157	52	0.4%	383	26	0.5%
Drilling and temp. Casing, Overburden	1,725	575	4.7%	171	57	0.4%	294	20	0.4%
Hard Rock Drilling	6,250	2,083	17.0%		-	0.0%		-	0.0%
Drilling Unconsolidated Formations	2,875	958	7.8%	12,450	4,150	31.1%	7,545	503	10.1%
Air Flushing	360	120	1.0%	60	20	0.1%	300	20	0.4%
Sampling and Borehole Logging.	38	13	0.1%	900	300	2.2%	2,070	138	2.8%
Casing	2,992	997	8.1%	5,100	1,700	12.7%	10,920	728	14.6%
Screen	1,628	543	4.4%	2,800	933	7.0%	5,980	399	8.0%
Gravel Packing, Sealing and Backfilling	1,119	373	3.0%	2,100	700	5.2%	5,510	367	7.3%
Well Development	1,440	480	3.9%	1,920	640	4.8%	9,600	640	12.8%
Pump Testing	1,622	541	4.4%	4,212	1,404	10.5%	8,279	552	11.0%
Water Sampling/disinfection	350	117	1.0%	579	193	1.4%	2,650	177	3.5%
Provisional Sum	6,100	2,033	16.6%	1,450	483	3.6%	3,550	237	4.7%
Sub Total	**33,387**	**11,129**		**36,428**	**12,143**		**68,171**	**4,545**	
Contingencies 10%	3,339	1,113	9.1%	3,643	1,214	9.1%	6,817	454	9.1%
Total	**36,726**	**12,242**	**100%**	**40,071**	**13,357**	**100%**	**74,988**	**4,999**	**100%**
Price per metre	193.29	USD		133.57	USD		99.98	USD	

Note: 3BH~70m imply a bid for three boreholes of an average depth of 70m
Source: Baumann *et al*., 2005.

- The example of Mpwapwa shows that mobilization and transport between sites make up 10% of the cost, or USD 1,000 per borehole.
- Screens for the same diameter boreholes are USD 543 per hole in the Mpwapwa bid and USD 933 per hole in the Rufiji bid.
- Well development and pump testing is USD 1,021 per hole in the Mpwapwa bid and USD 2,044 per hole in the Rufiji bid.

A systematic review of submitted tenders provides an overall picture of unit costs. Substantial cost savings is possible if discussions are held with drillers. However, decentralised procurement makes such an analysis more difficult (Baumann *et al*., 2005).

The analysis of the drilling cost as experienced in the RWSSP revealed the associate cost (Table 6.3). The investment plan for the NRWSSP is based on the following unit costs:

Table 6.3: Cost comparison NRWSSP versus RWSSP

	NRWSSP	RWSSP
Shallow well with Handpump	USD 2,400 (incl. Handpump, siting and construction work)	
Borehole with Handpump	USD 7,700 (incl. Handpump, siting and construction work)	USD 5,000 (excl. Handpump, siting and construction work)
Mechanised Borehole	USD 12,500 (incl. siting and construction work)	USD 12,500 (excl. siting and construction work)

Source: Baumann *et al*., 2005.

These costs include the full facility, i.e. sitting, design, drilling, supervision, construction, and supply of equipment. The drilling cost contributes to only about 50% of the full facility cost. The actual costs in RWSSP (Table 6.4) indicate higher costs above the expected typical cost for the facilities (Baumann *et al*., 2005).

Table 6.4: Actual Cost from Tenders in RWSSP

Type of BH	3BH ~70m		3BH ~100m		15BH ~50m	
	Hard Rock		Sedimentary		Sedimentary	
District	Mpwapwa		Rufiji		Rufiji	
Materials	2,030	16.6%	3,526	26.4%	1,671	33.4%
Fuel	1,275	10.4%	817	6.1%	223	4.5%
Labour charges	4,911	40.1%	6,686	50.1%	2,105	42.1%
Overheads	4,026	32.9%	2,328	17.4%	1,000	20.0%
	12,242		**13,357**		**4,999**	

Note: 3BH~70m imply a bid for three boreholes of an average depth of 70m
Source: Baumann *et al*., 2005.

7.0 WATER RESOURCES MANAGEMENT IN TANZANIA

7.1 Institutional and Legal Framework

The control of water affairs in Tanzania is under the ministry responsible for water, currently the Ministry of Water and Irrigation (MoWI). The regulatory and institutional framework for sustainable development and management of water resources (including groundwater) is provided for in the Water Resource Management Act no. 11 of 2009 (WRMA) that repealed the Water Utilization (Control and Regulation) Act No. 42 of 1974 and the subsequent amendment Act No. 10 of 1981 and No. 1989, Water Laws (Miscellaneous Amendments) Act No. 8 of 1997, and Water Laws (Miscellaneous Amendment) Act of 1999. The act outlines principles for water resources management, provide for the prevention and control of water pollution, and for participation of stakeholders and the general public in implementation of the National Water Policy of 2002.

The act provides for the water resources management through a River Basin Management Approach that was adopted in Tanzania in 1980s. The Country is presently divided in to nine river basins for purposes of water resources management, which include; (i) Pangani (ii) Wami-Ruvu, (iii) Rufiji, (iv) Ruvuma and Southern Coast, all of which drain into the Indian Ocean, and (v) Lake Nyasa, (vi) Lake Rukwa, (vii) Lake Tanganyika, (viii) Lake Victoria, and (ix) the Internal drainage basins of Lake Eyasi, Manyara and Bubu depression. The thrust of the current water resource management in Tanzania is to implement water management at the basin level. The National Water Policy (2002) recognises an institution framework that includes the water users at grass root level to the National Level. The management is set at five main levels; National level, Basin level, catchment and sub-catchment level, District level, and Community or Water User Association level which are considered the lowest level, bringing and integrating users of the same source (NAWAPO, 2002). The policy advocates for an integrated approach in water resources and addresses participatory, multi-sectoral, multidisciplinary river-basin management, which, recognizes that water is a scarce resource and integrates the linkage between land use and water use and recognizes the important role water ecosystems play in the national economy. Basically, the most recent approach reflects three major shifts:

(i) *Comprehensiveness:* A holistic basin approach for integrating multi-sector and multi-objective planning and management that minimizes the effects of externalities, and ensures sustainability and protection of the resource;

(ii) *Subsidiarity:* Decentralizing decision making and devolving to the lowest practicable level, with stakeholders participating in the planning, design, implementation of the management actions and decision making; and

(iii) *Economic:* Decision-making in the public sector, private sector and in civil society on the use of water should reflect the scarcity value of water, water pricing, cost sharing, and other incentives for promoting the rational use of water.

The Water Resources Management Act, 2009 (WRMA) introduced integrated water resources management (IWRM) principles into the management of the water resources of Tanzania. IWRM recognises the inter-connected nature of the hydrological cycle and promotes a river catchment or basin perspective to the management of water resources, even where these cross administrative and international boundaries. Water resources management includes planning the development of water resources, implementing the plans and all measures for allocation, conservation and controlling the utilisation of the water resource, all with the participation of the public. It calls for development without compromising the environment, seeking a balance that supports the natural systems and the social systems that define the ever-growing demand, disposal and pollution of water, and social sustainability.

A growing demand for food, growing competition between agriculture and other subsectors such as hydropower generation, inadequate access to safe drinking water, inadequate infrastructure, low incomes and low land and water productivity, deterioration in the and environment from soil erosion, water logging and salinization all affirm the need for an integrated and coordinated approach to the management of water resources provided for by the WRMA.

7.1.1 Water Resources Management Act: aspects essential to irrigation development

According to section 6 (2) of the WRMA (URT, 2009b), priorities in the allocation of water are domestic use, the environment and, subject to the availability of the water, socio-economic activities, in that order. Irrigation falls within the socio-economic category. Before any planned major water project is implemented, a Strategic Environmental Assessment is required to assess the impact of the water project (section 8 of the WRMA); and before a proposed development, such as irrigation, is implemented in a water resource area or watershed, an EIA must be carried out (section 9 of the WRMA) (URT, 2009b).

With the introduction of basin-based management of water resources, irrigation interests for both surface water and groundwater will, in terms of section 22, be represented on the Basin Water Board appointed for a basin and tasked with the management of water resources at basin level, in consultation with catchment and sub-catchment water committees of the basin established in terms of section 29 of WRMA. Allocation of water to the competing demands for water in any basin area will be granted against water use permits and will be based on the water resource-management plans in place and the availability of water in the basin concerned, subject to the prescribed allocation priorities (URT, 2009b).

One of the main principles of the WRMA is the development of 5-year water-resource management plans at catchment level, basin level and the national level. Central to the plans is the determination of the available water resources against the demands for water at the respective levels. Such water-resource management plans are supposed to show whether the demands for water can be supported by the available resources and if not, water-demand management programmes should be a component of the plans. It is at the planning stage that deficits in any area can be determined and inter-basin water transfers of water incorporated into catchment or basin plans. Water resource management planning provided for under Part V of the WRMA requires the irrigation sector to play an active role in ensuring that its needs are considered and catered for within the framework of the plans at each level. The inclusiveness of the organisation of water institutions introduced by the WRMA allows the representation of all interests in water in any basin as this has an impact on the equitable allocation of water for socio-economic purposes to users in the area.

7.1.2 Water use permits

Basin Water Boards may grant water use permits for the diversion, damming, abstraction, storage and use of water (section 43 of the WRMA). Irrigation, as a water user, will require a water use permit for its requirements. The WRMA sets out provisions subject to which permits will be issued and these include provisions relating to quantities to be abstracted, pollution, proper drainage of the land and the review of permits in circumstances of inadequacy of water. Permits will also be required for the abstraction and use of groundwater in any basin, account being taken of the water demands in the basin (section 54 of the WRMA). Whether or not groundwater can be used for irrigation in any area will depend on the conditions set by the Basin Water Board in the permit. The conditions will be determined having regard to what is considered a safe yield from any aquifer for purposes of sustainable abstraction (section 61 of the WRMA) (URT, 2009b).

WRMA is a new Act; many regulations to facilitate its implementation are in the process of being developed. The regulations will prescribe or give guidelines as to the discharge by basin water boards of their functions in the management, regulation, protection, monitoring and conservation of water resources. Water permits are currently being issued even though the water resources management plans are not yet in place as these too are still to be prepared.

The irrigation sector will also have to deal with issues relating to the classification of water as required under section 32 of the WRMA. Depending on the class to which a water resource has been assigned, the use of the water from the particular resource must be subject to the need to meet the quality requirements for the source. Particular water uses for in-stream or land based activities may be prohibited or regulated in order to protect particular water resources. Despite law provisions, there is no specific provision for groundwater use by smallholder farmers.

7.1.3 Water User Associations

An important feature of the WRMA is the provision under section 80 for the formation of water users associations (WUA) by agreement of the majority of a group of water users. The specified purposes for which WUAs may be formed are with respect to any one or a combination of the following:

- (a) the management, distribution and conservation of water from a shared water source;
- (b) the joint acquisition and operation of any permit;
- (c) the resolution of conflicts between members of the association with regard to the joint use of a water resource;
- (d) collection of water user fees on behalf of the Basin Water Board;
- (e) Representing the special interests and values relating to water used for public purpose such as in a conservation area.

However, once a WUA is registered, all water users in the area using the common source of water, irrespective of the purpose of the individual uses, will be required to become members of the WUA and will be bound by the constitution of the WUA. WUAs in the context of the WRMA are not confined to irrigation as is the case in some jurisdictions but embraces all water users in any given area. They should therefore not be construed as organizations of irrigators although this may well turn out to be the case by default in an area without any other significant users but irrigators.

7.2 Data Storage and Information Management

Boreholes have been constructed in Tanzania since at least 1930 up until the present day. The borehole database is maintained by the MoWI, Directorate of Water Resources in Dodoma (Baumann *et al.,* 2005). The database lists 9,242 boreholes as of 2005 and projections indicate that at least 10,000 boreholes have been drilled as of 2010 (*Interviews with Eng. De-Mzee at*

DDCA). However, the data entry is not consistent; many boreholes have no data recorded and for others the data are incomplete and lack coordinates. It is therefore difficult to establish how many of these boreholes are actually used to provide water. It appears that the shallow boreholes drilled by hand drilling methods were not recorded or only partially recorded.

The DDCA together with the river basin offices would need to establish effective data collection on all boreholes in the country. The design of such a database should be governed by the desire to collect all necessary data. Geologic description of the collected samples should reflect the hydraulic properties rather than a random description of what meets the eye. The geologic logs need to be recorded to reflect the entire section as the non-water bearing zones are also important to understand the hydraulic connectivity and correlate with nearby borehole data. Hence, the field data collection and the data entry should be modified, with the processing and ultimate use of the data in mind. The database should provide a complete and consistent description of the field conditions. Borehole data recording format should be comprehensive enough to include data from all sources and should at least include the coordinate, consistent sample descriptions, borehole and aquifer test results, and the quality of water. A need for transforming the existing database into a Management Information Systems (MIS) is foreseen.

7.3 Groundwater Monitoring

The Water Resources Division (WRD) within the Ministry of Water and Irrigation is responsible for quantitative and qualitative assessment and monitoring of surface and groundwater resources (http://www.maji.go.tz/divisions/index.php). It also deals with dam safety monitoring. To this regard, the division collects hydrologic and water use data; collects and manages all water well log data; develops hydrogeologic maps; issues water use permits; inspects existing water abstractions systems. It is also responsible for water resources planning and research, regulation, enforcement and environmental issues associated with water resources. Technical assistance is also provided on water well construction and abandonment, water-related engineering, flooding and floodplain management. The division offers a variety of educational programs to promote wise use of the national water resources. Among its functions, the division supervises the operations of the Basin Water Offices and provides them with technical support.

The Division comprises of five sections led by the Directors namely, Water Resources Planning, Research and Development Section; Water resources Monitoring and Assessment; Trans-boundary Water Resources Management Section; Water Resources Protection Section and Central Water Board Section with clear mandated responsibilities / functions for each established section.

The National Water Sector Development Strategy (NWSDS) restructuring gives the regulatory role to Basin Water Office (BWO) for all matters pertaining to water resources management. However, the Basin Water Office is not mandated to regulate rural water supply and this remains a responsibility of the Rural Water Supply Division (RWSD) under MoWI, which has the overall responsibility to provide supervisory and advisory services in the development of rural water supply and sanitation services, and to monitor the installation and performance of those services.

Section 57 of WRMA provide guidance on data routing to responsible organs and it states that any person lawfully engaged in drilling or exploring activities shall keep and submit any relevant data on groundwater to the Basin Water Board. As regard to mining licenses, Section 58 provides that the holder of a special mining license or a prospecting licenses granted under the Mining Act, or a petroleum prospecting license who encounters groundwater in any workings carried out under such license shall (a) promptly notify the Basin Water Board of any waters, (b) submit any relevant data to the Basin Water Board, (c) take all such measures necessary for the protection of groundwater against pollution; and (d) comply with any directions of the Basin Water Board regarding the protection or disposal of such water.

7.4 Groundwater problems

The current problems facing groundwater resources exploration, development and management for urban and rural dwellers in the country include (Mato, 2002; Sadiki, 2008; Kongola, 2008):

- Deteriorating quality (i.e. aquifer degradation) as a result of pollution;
- Overexploitation (in some cases e.g. parts of Makutopora basin supplying Dodoma Municipality are showing declining water levels);
- Decrease of yields in boreholes (e.g. some of boreholes in Sanawari area, operated by the Arusha Urban Water and Sanitation Authority;
- Poor workmanship during construction of boreholes which leads to caving in of boreholes and opening up deeper aquifers to pollution sources;
- No established safe distances between human activities and positions of boreholes;
- Inadequate public awareness on the importance and potential sources of pollution of groundwater resources;
- Inadequate institutional arrangement to regulate groundwater resources;
- Role of private sector in ground water development and management not yet well recognized;
- Lack of data: data is scattered, fragmented and usually incomplete;
- Lack of groundwater monitoring networks;
- Lack of groundwater resources management plans;
- Increased climate variability and change, bringing about uncertainty in terms of rates of replenishment.

As revealed, there are many potential problems facing groundwater resources exploration and exploitation in Tanzania. There are limited information existing on the present state of quantity and quality of groundwater. Before groundwater can be used on a large scale for irrigation or other uses, extensive research is needed.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The study has revealed various issues as regard to groundwater availability and management, and the interrelated aspects. Based on the study findings, the following conclusions have been arrived at:

(a) The general geology of Tanzania comprises mainly the Precambrian (Archaean, Proterozoic) and Phanerozoic (Upper Palaeozoic, Mesozoic and Cenozoic) formations. The Archaean rocks are characterized by a granite-greenstone terrain. The Tanzanian Craton covers the central part of the territory up to south and east part of Lake Victoria.

(b) The occurrence of groundwater is largely influenced by geological conditions. Hydrogeologically about 75% of Tanzania is underlain by crystalline basement complex rocks of variable composition and ages, but predominantly Precambrian, which form the basement aquifers (for example the Pangani and Makutopora basins). Other aquifer types include karroo (found in Tanga), coastal sedimentary formation of limestone and sandstone (e.g. Dar es Salaam), and the alluvial sedimentary sequence, which mostly include clay, silt, sand and gravel, and volcanic materials (e.g. Kahe - Pangani basin). The groundwater potential of every type of aquifer differs much from place to place or basin-wise.

(c) The hydrogeology of Tanzania has not been thoroughly studied and owing to that, the quantification of the groundwater resources of the country has not yet been possible because of lack of requisite data. In most cases, the only available information has been compiled from existing borehole log data.

(d) Groundwater development has concentrated mainly on shallow wells for domestic purposes over a wide part of the country (mainly rural areas). They are also commonly used in the peri-urban fringes where there is no distribution network and places with unreliable supply. Most boreholes are located in the internal drainage basin. The basin is characterized by semi-arid to arid conditions with rainfall less that 550 mm annually, making the dwellers dependent mostly on groundwater as the main source for water supply.

(e) The review has revealed that in areas where the static water level is less than 8 meters, shallow hand dug well fitted with hand pumps is feasible.

(f) There are limited extensive studies on recharge in Tanzania and owing to that the recharge rates are not known. Based on very approximate hydrological information estimates, the total ground water recharge on annual basis is estimated at 3,725 MCM (0.4 %). However, a general outlook on the various recharge estimates indicates that the values are greatly variable location-wise and are a function of the methods used. Basin recharge rates have direct implications on groundwater development potential.

(g) Boreholes drilled for domestic water supplies indicate variable yields. Some boreholes in the Dodoma plain have exceptionally high yields of about $460 m^3 hr^{-1}$. The average yield of boreholes (excluding Dar es Salaam and dry boreholes) is $11 m^3 hr^{-1}$. The average static water level of productive boreholes is about 17 metres and the average total depth 62 metres.

(h) The cost for boreholes in Tanzania is about USD 6,000 for hand pumps and USD 12,000 for mechanised systems. These costs include the full facility, i.e. sitting, design, drilling, supervision, construction, and supply of equipment. The drilling cost contributes to only about 50% of the full facility cost.

(i) Groundwater has not been extensively used for irrigation largely due to the following reasons:
- Detailed analysis on groundwater irrigation potential nation-wide has not been thoroughly explored. Most of the estimates are based on surface water information.
- Tanzania still has enough areas that are potential for irrigation using surface water resources. Irrigation high potential area is estimated at 2.1 million ha in gross.
- There is scanty information on the potential of aquifers and yields of individual boreholes.
- Limited groundwater resources management plan.
- Majority of people have inadequate understanding of groundwater resources and this has led to inappropriate development of groundwater.

(j) The borehole database is maintained by the MoWI, Directorate of Water Resources in Dodoma. However, the data entry is not consistent; many boreholes have no data recorded and for others the data are incomplete and lack coordinates.

8.2 Recommendations

The findings of this study and conclusions have revealed numerous issues as regard to groundwater development and management in Tanzania. Based on the study findings and conclusions of the study, the following recommendations have been made:

a) The on-going groundwater resources development in the country is being carried out without sufficient knowledge of the resource potential, in terms of quantity and quality, due to lack of data and adequate regulations to monitor the activity. This has led to under utilization of the resource, and in some places overexploitation and interference in the existing groundwater sources, notably in coastal areas, may result in saltwater intrusion. Therefore, detailed groundwater studies should be carried out to assess the recharge and available groundwater resources, and establishing the groundwater potential for irrigation in Tanzania. The areas most prospective for Groundwater irrigation include:

   - Mtwara, Coast, Morogoro, Ruvuma, Shinyanga, Kilimanjaro, Kagera, Lindi, Mwanza and Mbeya due to the dominance of unconsolidated sand and gravels water bearing formations that permits good yields and the existence of suitable soil for agricultural crop cultivation.

   - Singida, Mara, Iringa, Kigoma, Dodoma, Rukwa and Manyara due to predominance of the weathered and/or fractured Granites/Gneisses water bearing formations, including Arusha which is dominated by igneous rocks and the water bearing zones are mostly in weathered and fractured lava flows with suitable land for crop cultivation.

b) Groundwater in Tanzania is likely to be the key resource to improve the water supply coverage in many areas. It is also an important conditioning factor in regional environmental processes. The development of groundwater therefore should be carefully managed to make full benefit of its potential, to protect its quality and to guard against over-exploitation of the aquifers.

c) There is a need for transforming the existing database into a Management Information Systems (MIS) that is integrated into a Geographic Information System (GIS) for enhanced information sharing. Key information like boreholes location, groundwater quality, amounts of abstraction, and the hydrogeology should be maintained in the database.

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