TAMK University of Applied Sciences
Environmental Engineering

Final Thesis

Milda, Lisa

The environmental impact caused by the increasing demand for water. Water and resource management - a case study in Ethiopia.

Supervisor Principal Lecturer, Marjukka Dyer
Commissioned by Kestävä tulevaisuus ry, Tampere
Tampere 2009

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ABSTRACT

The global water crisis is facing the word and the lack of safe and supplied drinking water is threatening people worldwide. Especially in developing countries more and more people suffer from the missing or not usable water.

The aim of the thesis is to analyse the water situation in Ethiopia and of the city Bahir Dar, finding reasons for missing water supply and mismanagement of resources and impacts on the environment, that are caused by the use of water. Suitable recommendations for improvements were try to be done.

The main research method is based on theory. Books, reports and internet sources were used, as well as personal experience gained during a practical training in Bahir Dar, Ethiopia.

Foreword

More and more people suffer from inadequate water supply and do not have access to safe drinking water. Clean water is needed for the population's health and environmental sustainability. Water must be recognized for its value as an viable resource that sustain both society and economy.
My final thesis focuses on the situation of lacking water access and the environmental impact of increasing water use in Ethiopia. I am going to try to present the current situation and find (theoretical) recommendations for an adequate water and resource management in Ethiopia. In addition I will describe the water and sanitation supply situation in Bahir Dar, based on the "Municipal Infrastructure Assessment Report" for Bahir Dar and a project, dealing with the "Improvement of self-sufficiency and sustainability in sanitation, waste and energy in Bahir Dar".

I thank my parents who supported me in every way and made it possible for me to spent my semester abroad in Tampere. The positive experiences I gained there and during my stay in Ethiopia will accompany me for the rest of my life. The support I got, especially from Marjukka Dyer, the head of the environmental engineering department and my supervisor, was helpful and inspiring.
I also thank Kati Hinkkanen and Abel Terefe, who were really helpful and supporting by organizing my stay in Bahir Dar.

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Abbreviations

UN	United Nations
SIWI	Stockholm International Water Institute
A 21	Agenda 21
IWRM	Integrated Water Resource Management
MDG	Millennium Development Goal
WHO	World Health Organization
PRSP	Poverty Reduction Strategy Papers
HDI	Human Development Index
WWAP	World Water Assessment Program
MoWR	Ministry of Water Resources
WRDP	Water Resource Development Program
WSDP	Water Sector Development Program
WWDR	World Water Development Report
EEPA	Ethiopian Environmental Protection Authority
UNDP	United Nation Development Programme
TDS	Total Dissolved Solids
ppm	Parts Per Million (10^{-6})
WB	World Bank
EIA	Environmental Impact Assessment
IWMI	International Water Management Institute
ANRS	Agence Nationale de Recherche sur le Sida
WRDB	Water Resources Development Bureau
CSA	Central Statistical Authority

1. Introduction

"Water is a limited natural resource and a public good fundamental for life and health. The human right to water is indispensable for leading a life in human dignity". (General comments No. 15, 2002) /31/

Since water is a natural limited source, but fundamental to life and health of human beings, the pressure is increasing to provide clean drinking water to people.
In 2000, the World Health Organization (WHO) rated, that 1.1 billion do not have adequate access to safe drinking water and at least 2.4 billion live without sanitation.

As the demand increases, water resources are becoming more an more scarce. The growth of population, the economic development and changing trade policies are the main responsible impacts of the increasing demand and need for water. Water use has been growing at more than twice the rate of the population increase during this century. By 2025, two thirds of the world's population could be living in countries with an enormous scarcity of fresh water. /22/

The development and management of water resources could have an important influence of obviation of water-related diseases, preventing water pollution and assure the availability of safe water, where needed.

Ethiopia is one of the world poorest countries according to the UN list of least developed countries. The country is facing the demand of water daily. The access to an improved water supply is only available among 22 % of the population. The sanitation situation is even worse with only 13% of adequate sanitation services. /13/

The country has experienced droughts followed by shortages of food and water supply. Especially the surface water sources, such as springs and ponds, dry up. /13/ The remained and limited water sources become contaminated by environmental waste, such as human and animal excreta.
Especially in rural areas, sustainable resource management is essential for balancing the growing demand of water with available resources.
The reuse of sewage is not handled properly. Over 80 % of the sewage water in

developing countries is piped directly into rivers, lakes and coastal waters, without having any waste water treatment before. The decline of water quality has consequences not only on human but also on environmental health.

Especially in developing countries the so called “global water crisis” is an upcoming problem the population has to face. Climate change, overpopulation and poverty are possible reasons for the imbalance of water use and water sources.

The decreasing water quality is also a threat for the amount of safe water; since there is a clear linkage between water quality and water quantity. It is important to consider this, while managing and analysing water quantity and water quality. Hence, one of the objectives of the 2nd World Water Forum in 2000 was “to ensure the integrity of ecosystems through sustainable water resources management”. /32/

2. Background

Both developing countries and industrialized countries are concerned by the alarming changes within the water sector.
There are technical/scientific issues, related to the critical development of the quality and quantity of freshwater, consequences of the climate change or the wide spread shortage of water supply and disposal services.
Concurrently, there are structural and organizational issues concerning the water supply and distribution. How can structures and goals be optimized? Which tools are suitable to be used?

2.1 Water and resource management

A sustainable management of resources is essential to ease the tension between the demand and the availability of freshwater. A vital ecosystem provides necessary services to human beings in order to secure food, hygiene standards and sustaining life.

The main objectives of water (resource) management is to control the utilisation and development of water resources in an efficient, environmental friendly way, to cope the *"society's demand for water, water-related goods and services, as well as to safeguard the ecological functions of water resources"* (UN Economic Commission for Africa). /17/

The planning and managing of water resources should also focus on socio-economic, environmental and technical areas. An adequate water management affects the quality and quantity of water sources, protects the biological diversity and the intactness of aquatic ecosystems.

2.1.1 Integrated Water Resource Management

In recent years, the Agenda 21 (A 21) and the therefore deduced *Integrated Water Resource Management* (IWRM) formulated objectives and requirements regarding the management of waters. The IWRM has a holistic view on the treatment, planning and management of water sources with less use of valuable resources.
The objective of this process is to maximize the social and economic welfare without detracting the vital ecosystems, using justifiable conditions in the utilization of resource. This means that environmental goals are compatible and linked with economic and social objectives. Therefore, the active participation and cooperation of various social and private actors in the planning and decision-making processes is necessary.

Technological progress has increased in recent years and new methods for processing drinking water and waste water purification are available. These procedures allow new solutions, which are not any more linked to central systems for water supply and disposal. Water saving installations, for example, reduce consumption without loss of comfort, advanced filters provide good water quality, the establishment of a recycling loop for water reduces water consumption.

These new approaches are also opportunities for emerging and developing countries. In areas with water shortages, the most urgent task remains to find access to water sources. However the efficient and economical use of water resources is essential.

2.1 United Nations: Millennium Development Goal

The MDG (Millennium Development Goal) 7 gives attention to *"ensure the environmental sustainability"*.
Many developing countries suffer from inadequate drinking water supply and sanitation. The development objectives of the Millennium Summit of the United Nations in 2000 and the World Summit on Sustainable Development in 2002, stipulated to halve the rate of people without access to safe drinking water and adequate sanitation by 2015 (Target 10). /27/
Also the International Conference on Water and the Environment, Dublin 2002,

proposed following principles, also known as *"The Dublin Principles"*:

A. Freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment.

B. Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.

C. Women play a central part in the provision management and safeguarding of water.

D. Water has an economic value in all its competing uses and should be recognized as an economic good. /10/

The WHO (World Health Organization) presents mixed results by now. Although the world is on a good way to meet the drinking water target by 2015, Sub-Saharan Africa is still an exception (2004). /30/

3. Ethiopia

The Federal Democratic Republic of Ethiopia is located in the east of the horn of Africa. Ethiopia is a landlocked country bordered by Eritrea, Sudan, Kenya, Somalia and Djibouti, as shown in figure 1.

The country has three climatic zones, from dry or humid hot to cool temperatures around zero degrees in the highlands. Ethiopia, with about 1.14 million square kilometres, has a population of just 76.5 million (July 2007 est.) million inhabitants. Approximately 80% of the population lives in rural areas. The population density is over 60 inhabitants per square km.

Agriculture is the predominantly sector of the country with over 80 percent of its population farming on about 15 - 20 percent of the arable land. /16/

Fig. 1: Map of Ethiopia /14/

There are nearly 80 languages spoken in Ethiopia, but the most common are Amharic, Tigrinya, and Oromigna.

3.1 Ethiopian Development

Ethiopia, as the second-most populous in Sub-Saharan Africa, is one the most impoverished African country. On the Human Development Index (HDI) rank, it is allocated on 169 out of 177 countries. /23/ Mostly in rural areas, a large proportion of the population lives below the national poverty line. Iterative droughts contributed to regular food shortages and famine. The food situation is drastic. Additional reasons to the droughts, are e.g. the high population growth, a poor road network for freight transport, low harvests in agriculture, the destruction of forests and the soil erosion on arable land.
The continuous trend of urbanisation raises a problem to environmental sustainability in Ethiopia. People migrate to urban areas, rather than solving the challenges of degraded land and water resources in the rural areas of the county.
There is no systematic domestic or industrial waste and sewage disposal. The consequences of climate change as seriously evaluated for Ethiopia.

Although Ethiopia became a federal democratic state in the 1990s, its institutions are still relatively new and inadequate political systems affect the development. The limited achievement potential is further restrained by low government revenues. Ethiopia has problems to achieve the MDG's, as shown in Table 1.

Table 1: Millennium Development Goals for Ethiopia, compiled from UNDP /24/ and WB

MDG (UNDP)	**1990**	**2000**	**2004-05 PRSP-Goals**	**Achieve Global MDG by 2015?**
Access to clean water	19%	30%	39.4%	Possible in urban areas
MDG (World Bank)	**1990**	**1995**	**2000**	**2007**
Improved sanitation facilities (% of population with access)	4%	5%	7%	11%
Improved water source (% of population with access)	13%	20%	29%	42%

The recent years of rapid population have contributed to over-farming and deforestation, which have degraded the environment and undermined development. /29/
Table 2 shows the population growth for different time periods.

Table 2: United Nation, World Population Prospects, Ethiopia /25/

Period	Population growth rate
1980-1985	2.96%
1985-1990	3.25%
1990-1995	3.31%
1995-2000	2.79%
2000-2005	2.61%
2005-2010	2.59%
2010-2015	2.49%
2015-2020	2.30%

Despite these problems, Ethiopia has development potential: The productivity of agriculture is increasable, the country has untapped natural resources and environmentally friendly energy sources such as hydro power.

3.2 Water sources of Ethiopia

Ethiopia provides extensive water resources and wetland ecosystems, including twelve river basins, about 14 major lakes, and some artificial reservoirs. About 122 billion cubic meters of water run off annually from the above sources. Most of these rivers are trans-boundary. The country has also a certain amount of ground water resource, but the potential has not been assessed in detail. /21/
Table 3 lists the internal renewable water resources in the country.

Table 3: Internal renewable water resources in Ethiopia /34/

Renewable water sources		
Average precipitation	848	mm/yr
	936	10^9 m^3/yr
Internal renewable water resources	122	10^9 m^3/yr
Total actual renewable water resources	122	10^9 m^3/yr
Dependency ratio	0	%
Total actual renewable water resources per inhabitant	1 685	m^3/yr
Total dam capacity	3 458	10^6 m^3/yr
Water withdrawal		
Total water withdrawal	5 558	10^6 m^3/yr
- irrigation + livestock	5 204	10^6 m^3/yr
- domestic	333	10^6 m^3/yr
- industry	21	10^6 m^3/yr
• per inhabitant	81	m^3/yr
• as % of total actual renewable water resources	4.6	%
Non-conventional sources of water		
Produced wastewater	x	10^6 m^3/yr
Treated wastewater	0	10^6 m^3/yr
Reused treated wastewater	0	10^6 m^3/yr
Desalinated water produced	x	10^6 m^3/yr

3.2.1 Surface water

Ethiopia's topography and the areal distribution of the surface water limit partly the utilization of these fresh water resources. The annual renewable fresh water resource amounts from 110 to 122 km^3 per year, spread over the river basins. About 70 % of freshwater is provided by the Abbay basin (Blue Nile). From the available water resources, only 9 % remains in the country, the majority flows to the neighbouring countries (UN, Country profile, 2002).

The major river basins of the country are listed in table 4.

Table 4: Major river basins, catchments areas and annual discharges in Ethiopia, Compiled from UN WWAP

Basins	Catchment area km²	%	Annual discharge billion m³	%
Abay	199,812	17.56	54.4	43.05
Awash	112,700	9.90	4.90	3.76
Baro-Akobo	74,102	6.51	23.23	19.31
Genele-Dawa	171,050	15.03	6.10	4.81
Tekeze	90,000	7.90	8.20	6.24
Wabi-Shebele	200,214	17.59	3.16	2.59
Omo-Ghibe	78,200	6.87	16.60	14.70
Mereb	5,900	0.52	0.72	0.21
Rift valley lakes	52,740	4.63	5.64	4.62
Danakil	74,0002	6.50	0.86	0.70
Ogaden	77,100	6.77	0.00	0.00
Aisha	2,200	0.19	0.00	0.00
∑	1138,02	82.41	46.18	99.99
Total	1138,02	100	123.81	100

Most of the lakes are in the area of the Rift Valley. Water quality (drinking water) of the lakes are poor due to the presence of saline and alkaline springs in the Rift Valley. Lakes outside of the Rift Valley are fresh water lakes.

Ethiopia also possesses several rivers. Table 5 lists the major river and their lengths.

Table 5: Major Rivers in Ethiopia

River	Length in km
Abay	800
Wabi Shebele	1000
Genale	480
Awash	1200
Omo	760
Tekeze	608
Mereb	440
Baro	277
Angereb	220

Most of the data is missing and as table 6 shows, observation has not been done over a long time period, yet.

Table 6: Observations of river run-off in Ethiopia /6/

	Area, Km^2x10^3	Number of observation Stations	Area per station, Km^2x10^3	Number of years Of observations
Ethiopia	1222	10	122	1 – 6

3.2.2 Groundwater

Groundwater has an important factor as an addition to the availability of surface water resources in providing drinking water for the citizen and for economic use (e.g. agriculture and industry), especially in regions with polluted or limited (or saline) surface water. Approximately 29 % of the world's freshwater is stored in aquifers. It is estimated that about 23 % of that volume is on the African continent. /7/

The use of groundwater in Ethiopia is detained by the lack of understanding, technical supply and information. Ethiopia's potential of groundwater is estimated to be 2.6-13.5 billion m^3/year, which could be technically developed for consumptive purposes, but only a small amount of this is explored and used. /18/

Figure 2 shows the estimated distribution of groundwater availability in Ethiopia.

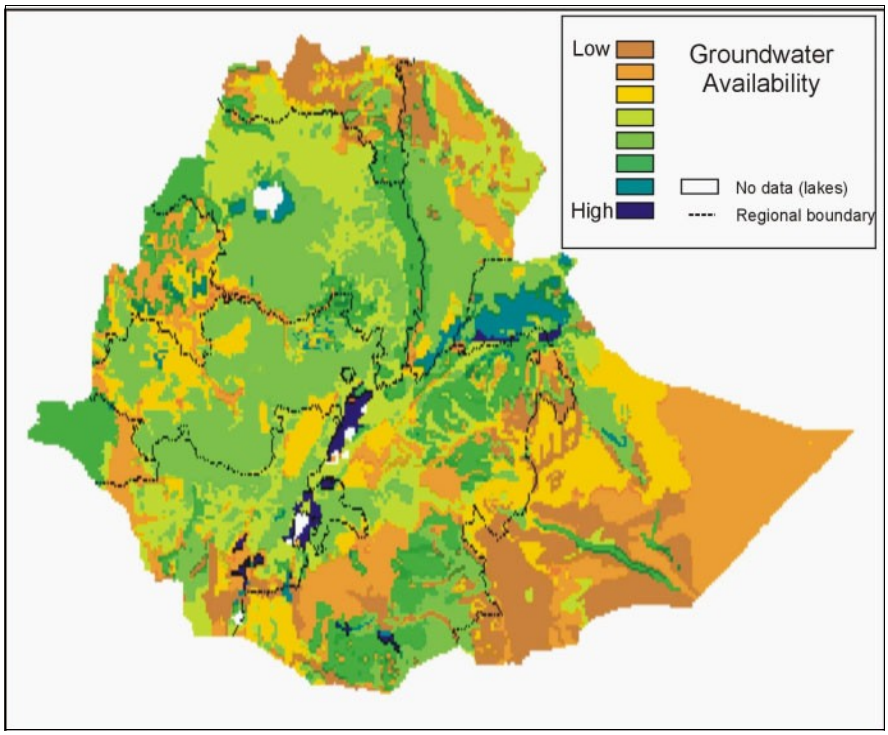

Fig. 2: Groundwater availability in Ethiopia /28/

Especially the lack of sufficient hydro – geological data makes an evaluation of groundwater resources in Ethiopia difficult.

3.3 National water policy

The government implemented a water resources management policy in 1999.
The Ethiopian Water Resources Management Policy outlines some fundamental policy principles based on the Dublin-Rio statements (1992). /26/ The aim is to promote an efficient and effective utilization of the country's water sources.
Regulations on water resources have been developed and were approved by parliament in the year 2000.

The ministry of water resources (MoWR) was established to manage the water resources of Ethiopia, including the development of new and sustainable polices, *"strategies and programs, implement water sector laws and regulations, conduct study and research activities, provide technical support to regional water bureaus and offices and sign international agreements"* (MoWR, 2007). /21/
The ministry itself admits failures in the country's rural water supply and sanitation services. Main problems are mainly shortage of skilled manpower, the poor project management, missing monitoring and evaluation, poor maintenance and unsatisfactory long-term water quality control.

3.3.1 Water Resource Development Program

The Water Resource Development Program (WRDP) is a part of the Water Sector Development Program (WSDP) of the MoWR. It was established for a sustainable development and management of water resources. The aim is to assure maximum economic and social benefits from available water resources, while basic human needs are met and the protection of the environment is ensured. /21/
Figure 3 shows the percentage of share of various programs in the WSDP and the distribution of the projects to achieve the water policy objectives.

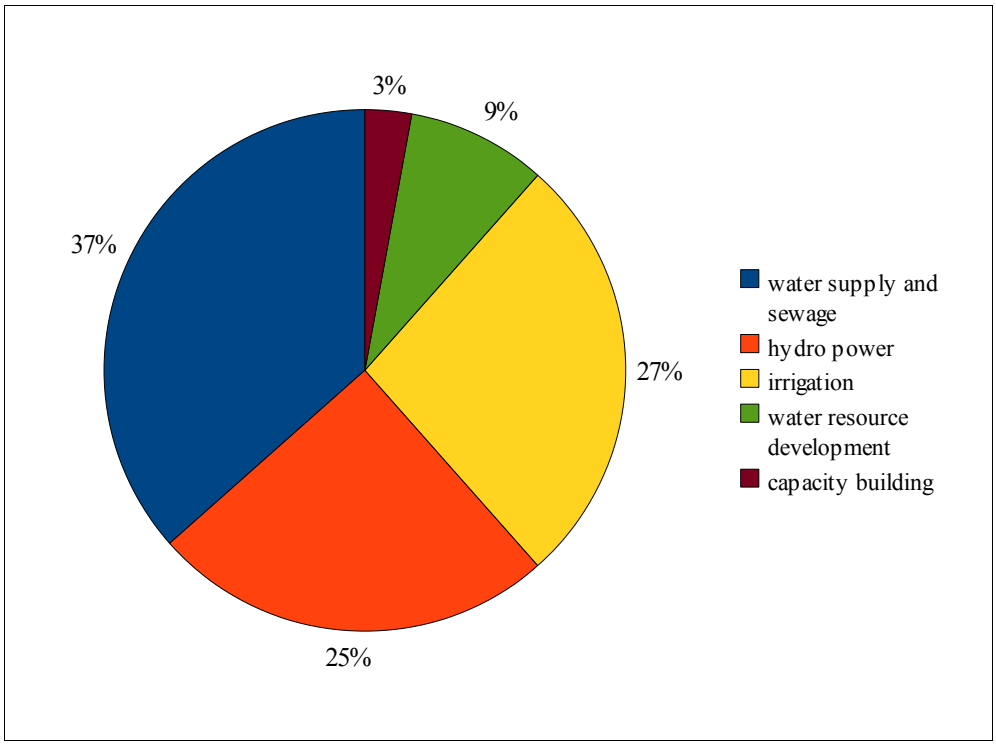

Fig. 3: Percentage share of various programs in the WSDP

3.4 Water use

Much statistical information and data about the national water use is not available, but agriculture is the major water-consuming sector.

The estimated amount of used water per year is about 5.2 km^3, based on the total irrigated area, while domestic and industrial water withdrawals are estimated to be about 0.33 and 0.02 km^3 respectively as shown in figure 4 below. /34/

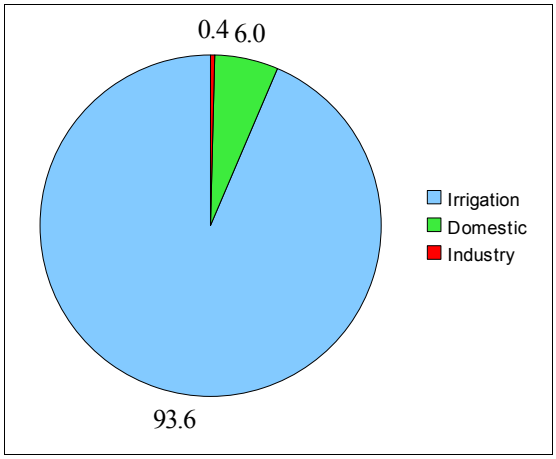

Fig. 4: Water use in Ethiopia in 2002, FAO

The conflict between the environment and the agriculture is increasing, due to the the growing demand of water for irrigation. Surface water bodies are diverted and overuse of aquifers is leading to desiccation, which has consequences for ecosystems.
Using groundwater sources for irrigation has not been considered so much in Ethiopia, mainly because of high investment and running costs and also because of the availability of surface water, but pilot schemes have been started (Raya Valley in Tigray Region). /34/

4. Impacts of water use on water systems and the environment

Water is essential for human life as well to economies. Most domestic and industrial water uses include withdrawals from surface or groundwater resources. Nowadays, the intensity of human activities determines the quantity and quality of water sources. Depletion and pollution are consequences of the increased water usage, which *"increased sixfold, twice the rate of population growth"* (State of the World, 2008). The increasing demand for water accelerate these effects. Especially in developing countries, where the demand is high and the availability of water supply is lowest, environmental aspects of water consumption are mostly not regarded. The government or national responsible for water management neglect that a sustainable development and environmental protection have to be closely linked.

4.1 Water scarcity

According to the growing world population, it is estimated that by 2025 more than three quarters of the population will face water scarcity. /10/
One differs between physical and economic water scarcity:
1) Physical water scarcity has a limited access to water. The demand for water is higher than the ability of water supply. Mostly dry or arid regions are associated with physical scarcity. These conditions can also be man-made, when sources of water are overused and leading to physical scarcity downstream.
2) Economic water scarcity emerges when human, institutional and financial capital limit access to water. /10/ The unequal distribution of resources is what much sub-Saharan states, including Ethiopia, suffer from.

Figure 4 shows the allocation of both physical and economic water scarcity in the world.

Ethiopia suffers, according to the map below, from economic water scarcity.

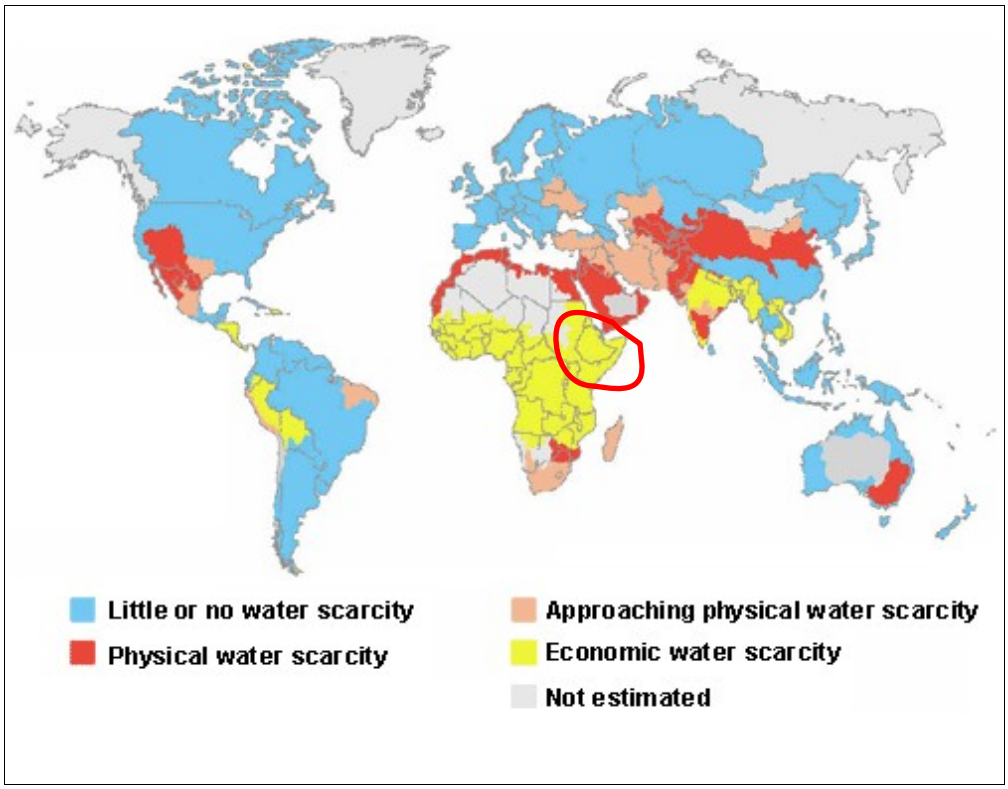

Fig. 5: Physical and Economic Water Scarcity /17/

4.2 Water pollution

Water pollution arises when water bodies get affected by sewage, toxic chemicals, metals, oils or other substances. /33/ Surface water as rivers, lakes and oceans, as well as ground water can be polluted and can harm species of plants and animals. The World Health Organisation estimates that about 5 million people die, because of polluted drinking water. The main source of water pollution in Ethiopia is sewage of domestic and rural waste water, industrial and agricultural activities. /33/

4.2.1 Human impacts

One type of waste, that has to be considered first, is the human waste itself. /8/ Inadequate disposal of liquid waste and human faeces can lead to serious water contamination. The World Water Development Report (WWDR) evaluated that about 80 % of waste water in developing countries is led untreated into the environment.
In Ethiopia, the majority of population that lives in rural areas, and also some that live in the urbanisation, do not have access to a proper sewer system. Human wastes, like faeces and urine therefore contaminate water sources. The utilization of these waters causes serious health problems for the population. The sewage creates also toxic reaction and benefits eutrophication in water bodies, because of the high nutrients loads, which consequences are the reduction of water quality. Indeed, the aim of access to sanitation must be accompanied by sewage treatment.

The industrial sector of Ethiopia is still a not as important as for instance the agricultural sector, but also has major impacts on the environment and water sources of the country. The EEPA published in 2006, that studies confirmed the disposal of industrial effluents (in Addis Ababa) into nearby water bodies and open land without any form of waste water treatment. Also the MoWR conceded that e.g. the Awash river is threatened from industry and increasing population. *"This is because most of the existing industries and major towns [...] have no treatment plants for discharge of their waste"*. (MoWR, 2007)

The agricultural sector is the major income source for the country and the bigger part of the population is dependent on farming. Nearly 70 % of all freshwater worldwide is withdrawn and used by agriculture and also consumes the most water through plant evapotranspiration. /9/ An intensive application of agrochemicals (agricultural chemicals) leads to degradation and pollution of available land and groundwater, because parts of the used fertilizers is drained into the surface and groundwater systems, with possible long-term effects on human health and ecosystems. The WWDR estimated that the input of nitrogen into soil and rivers will increase about 10 – 15 % because of the higher need of food for the growing world population, which will intensify also the agricultural activities in Ethiopia. The run off of fertilizers also have the effect of eutrophication and stresses ecosystems.

Major prevalent water quality problems in Ethiopia are those related to physical, chemical, as well as microbiological parameters, the possible causes of which are natural, anthropogenic or both. Some of the major water quality problems are shown below in table 7.

Table 7: Water Quality Problems in Ethiopia /26/

	Water Quality Problems	Parameters of Concern
1	Physical parameters	colour, odour, turbidity, taste
2	Chemical Qualities	iron, hardness, pH, Nitrate, Fluoride, Sulfate, Nitrite, Manganese, CO2, TDS
3	Microbiological Parameters	Total coliform, E.coli, giardia, amoebae

4.2.2 Pollution Control

It is important to monitor the quality of the water and ensure it *"by setting both the standards and the frequency of sampling"*. (Patrick J. Sullivan, 2005) /8/ The recorded data should be used to provide reliable information about actual situations and to discover and predict possible sources of pollutions in order to avoid or reduce them. In Ethiopia there is no systematic and comprehensive water quality assessment. /21/ Consequently, there is a need to have an appropriate law or regulations, which set standards for the monitoring of (drinking) water quality.

Absolutely pure and drinkable water is rather uncommon. Before approving of potable water, controlling and treatments are necessary. The differences in priorities of water treatment in developing countries like Ethiopia are mainly to provide micro biologically safe water, to prevent water-borne diseases. Preferable is that the water source itself requires little or no treatment and the source is protected, rather than to use a lower-quality source, which requires water treatment.

Where treatment is necessary for short-term aims, basic treatments are used *"to provide aesthetically acceptable water and effective disinfection"*. (Chris Binnie, 2006) /3/ Long-term treatment objectives should meet the standards set by the 'WHO guidelines for drinking water quality'.

The threat of incomplete understanding of the impact of pollution and the consequential stress of ecosystems are major problems for failed pollution control. Also monitoring of negative effects of water use on the environment is essential to prevent irreparable damage on water and ecosystems.

4.2.2.1 Water Quality Standards

With financial support of the United Nation Development Programme, the MoWR developed a national drinking water quality guideline in 2000. This, however, is still in a testing phase.
It is strongly recommended to formulate binding water quality standards and legal limits for pollutants. These help to control water quality and protect water bodies from domestic and industrial effluents.

5. Recommended good practices

The following part of the thesis deals with several recommendations, focusing on efficient water management and environmental problems caused by the demand for water. Since this work is mainly based on theoretical approaches, the solutions are not only applicable on Ethiopia, but, nevertheless, concentrate on main problems in the country.

5.1 Water Demand Management

The main aim of the water sector in Ethiopia should be to prevent water loss and manage available water sources for a sustainable use. Demand management is a method to save water, energy and money through increased efficiency. It applies different techniques to conserve water and improve the efficient utilization of water. Additional factors, such as 'technology improvements', 'management approaches', 'economic incentives' and 'legal and regulatory approaches', are necessary for successful water management.

5.2 Successful Irrigation

The World Bank (WB) estimated that the efficiency of irrigation is almost below 50%. Adequate management practices, specially with conveyance systems, could help to achieve an irrigation efficiency up to 90%. /11/
Available sources of the country for irrigation are rainwater harvesting, rivers or lakes,

or shallow and deep groundwater reservoirs. The agricultural sector in Ethiopia is dependent on rainfalls, because only 5 - 10 % of potentially irrigable land is actually under irrigation. Different irrigation projects with the aim to ensure agricultural productivity have been implemented in Ethiopia to utilize the ground water potential of the country. Several factors, such as missing equipment, financial support and no adequate knowledge and skills still impact the development.

Methods that are easy to apply are relevant for a successful irrigation in developing countries. Nevertheless, an assessment of environmental conditions before and after the implementation should not be neglected, as well as the environmental sustainability of the irrigation schemes, especially soil salinity problems and erosion. A common tool is the so called 'Environmental Impact Assessment' (EIA).

Table 8 summarizes possible environmental impacts of irrigation, which are to avoid by (pre-)management and EIA.

Table 8: Environmental impacts of irrigation. Compiled. /11/

Factor	Positive impact	Negative impact
Engineering	Improvement of water regimes of irrigated soils. Possibility for use and disposal of waste water.	Rise in groundwater table, danger of water logging and salinization of soils. Changes in properties of the reservoir water. Removal of vegetation in the area to be irrigated.
Health	Greater crop and fish production improves the nutritional status and health of the people.	Possible spread of diseases such as schistosomiasis. Danger of pollution of water by return flow from the irrigation. Possible infections from waste irrigation.

There are different types of irrigation systems. Main factors, that influence the selection of irrigation types are the natural conditions, such as soil type, slope, climate, quality and quantity of water and the type of crop that is to be irrigated.

Examples of irrigation types are shown in figure 6. An other name for the pictured 'part flood' is 'furrow irrigation', where narrow ditches are dug between the row of crops and the water is absorbed and is wetting the soil of the furrows. /19/

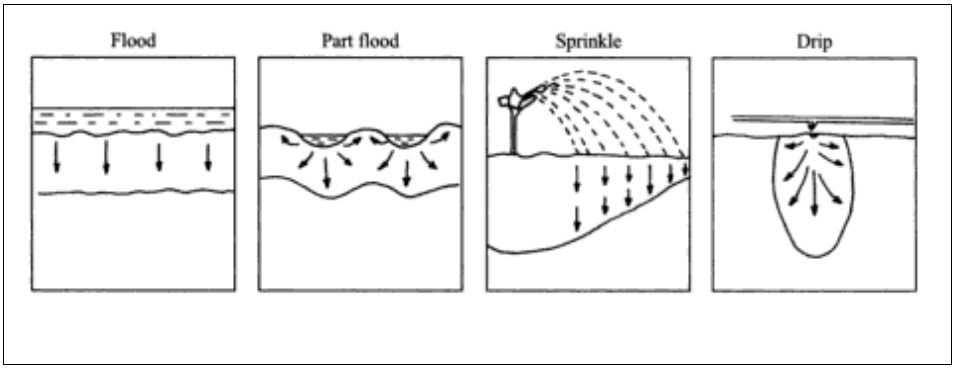

Fig. 6: Alternative irrigation methods /11/ p.215

Drip irrigation and subsurface irrigation are one of the most efficient, because the localized water supply reach the plant directly. The subsurface irrigation scheme has also the advantages of controlling the level of naturally occurring shallow groundwater. It is estimated that less than 0.5 % of the world's irrigation schemes are relied on drip techniques. Thus it appears that there is a potential for great water savings. /1/

5.2.1 The Use of Waste Water in Irrigation

The use of waste water in agriculture is common in low-income countries. There are both positive and negative impacts of the utilization of waste water either for the crop production, the soil, health or the ecosystem. A challenge for local legislation in developing countries is to protect public health and environmental systems through legislation and regulations. The application of waste water for irrigation requires treatment and the removal of pathogenic micro-organism. /11/

5.2.2 Enhancement of water efficiency

The major aim of irrigation is to enhance the efficiency of the use of water and to minimize the waste of valuably water. Efficient irrigation methods help to prevent the losses of water. It should be ensured that irrigation water is not wasted:

1) The water that is need for irrigation should be available on demand (“crop demand – dependent irrigation schedule”).
2) To avoid evaporation losses, surface irrigation should be applied in the morning or evening.
3) Irrigation water should be properly priced in proportion to the quantity used per unit area of land. /11/

5.3 Environmental Impact Assessment

As mentioned above (chapter 5.1.1) EIA is an important tool also for water management. "*It identify and evaluate the consequences of a proposed development, project, programme or policy"*. (C.J. Barrow, 2005) Every project related to water (or other sectors) should have an obligatory EIA. Among other things, Ethiopia's environmental situation is a consequence of unwise use of natural resources and unplanned development projects. Especially the stage of planning has not given much attention to environmental impacts. As devastating consequences, the country has experienced a serious degradation of natural resources and damage to ecosystems. /35/

5.3.1 Environmental Risks – involved in projects

Additionally, environmental risks are to prevent, because those mean the delay or the prevent of a project completion. Also costly redesigns could be consequences of missing prevention of environmental risks. Growing concern about the environment supports, luckily, the importance that environmental risks are evaluated in an EIA. /2/
A scheme of further possible risks involved in water projects is shown in figure 7.

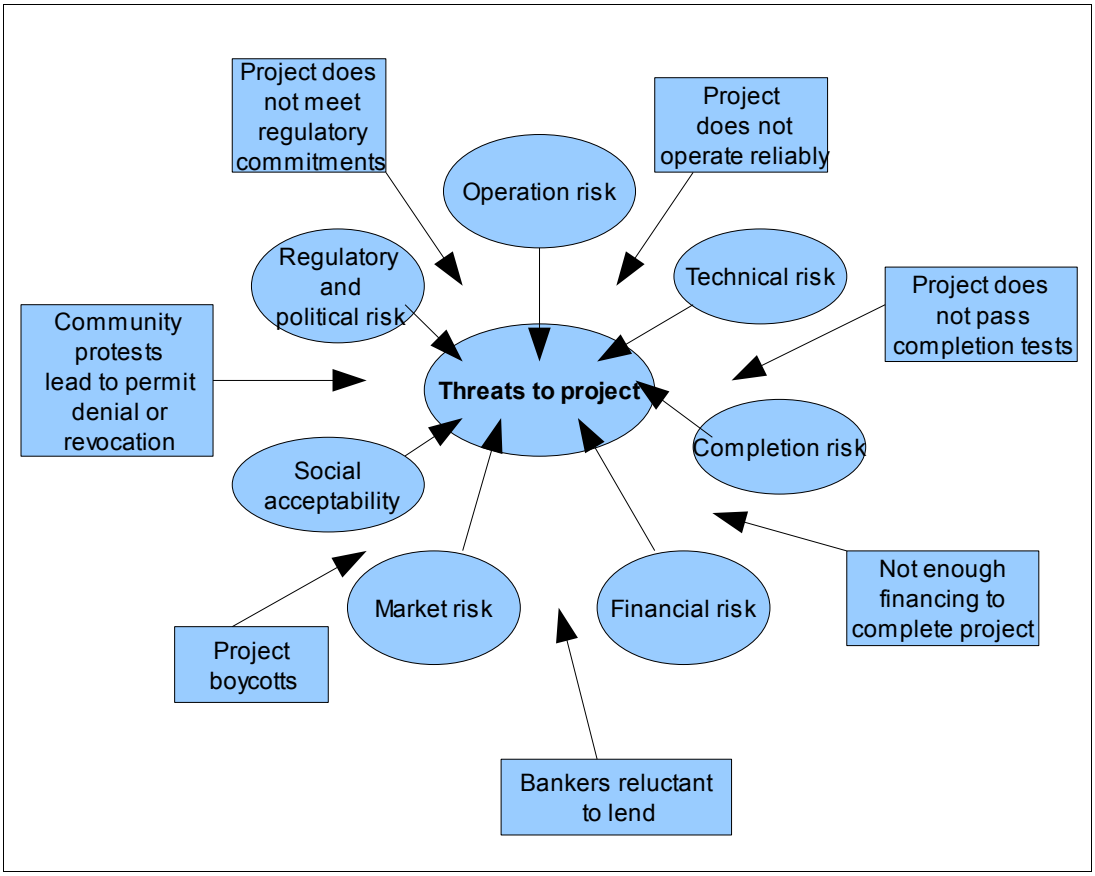

Fig. 7: Overview of the possible risks involved in a water project. /2/

5.4 Groundwater Management

Ethiopia's groundwater potential is as mentioned above quite high. Most of the developed groundwater resources are mainly used for domestic and industrial water supply, although much reliable data is not available.

Groundwater plays a vital role in many urban and rural areas, because its quality is generally good and does not need extra or much treatment. Also the security of groundwater as a source during dry periods is given, as well as the suitability for private use (e.g. wells and bore holes).

Nevertheless, the consequences of long contact times with the soil and sediments are high quantities of solved minerals. High fluoride concentrations are prevalent in most of the boreholes and springs in the Rift Valley and exceed with over 1.5 parts per million (ppm) the limits for drinking water (WHO). /21/ Contamination of groundwater through domestic and industrial effluents or leaking tanks are also threatened. However, groundwater is known to be the only or safe water resources to some areas. /26/

The aim of proper groundwater management is to make the source more sustained in a situation of increasing demand of water. To avoid the overexploitation of this resource, monitoring of water use and water tables is necessary for creating a stabilized situation. Since groundwater and surface water are hydrologically connected with each other, aquifers cannot be managed in isolation. /2/

6. Water supply and sanitation situation in Bahir Dar

Bahir Dar is the capital of the Amhara region and one of the biggest cities in Ethiopia. Lake Tana, the largest in Ethiopia, is located in the south of the city and is the origin of the Blue Nile. Bahir Dar is also an important manufacturing centre and tourist destination. According to the Central Statistical Authority (CSA) the city population grows to over 200 000. /38/

6.1 Infrastructure

The partly inadequate infrastructure and also the limited financial resources constrains productivity and economic growth. The absence of systematic approaches to monitoring and assessing restrain the flow of information and decelerate project works.
The road network has good and satisfactory condition.
During rain seasons, water logged and swampy condition could occur and some areas have to deal with flooding. These are the consequences of the city's flat topography. The soil in the area is also relatively impermeable and in times with heavy rainfall the water does not have the possibility to drain away. The available drainage system, which is consisting simple earth channels (about 60 %) and open and uncovered masonry channels, is underutilized and studies have shown that these channels need further improvement. /36/ As recommend by Ayalew Wondie, drainage systems prevent clogging caused by erosion and improper drainage. The constructions, also private drainage channels, should be be evaluated and monitored. /38/

6.2 Water Supply

The presence of natural springs with good water quality supports the availability of water supply in Bahir Dar. The ANRS invested in upgrading and expanding the city's water system.
The Bahir Dar Water Supply Service declares that around 96 % of the city's population has access to drinking water, either through private connections or conveniently located public tabs. Approximately 12 000 households get their water through private water connections and services. The flow rate of the 2 springs (see 6.2.2) is estimated to be 13 320 m^3/d. The average reported consumption is 5 367 m^3/d, which result in an unaccounted water ratio of over 55 %. Reasons could be leakages in the older part of the distribution network. The amount of 55 % water losses seems rather high, so that there

is a urgent need to analyse the situation and recheck the data.
The water is distributed from the reservoirs and is supplied to the consumer through 33 public fountains , 9 567 yard and house connections, 446 commercial connections, 314 government and public and 66 industrial connections (Metaferia Consulting Engineers, 2005). /39/

6.2.1 Water Supply Management

The Bahir Dar Water Supply Service, a semi – autonomous enterprise, controls the water supply of the city. The ANRS Water Resources Development Bureau (WRDB) gives technical support in capital planning, design, data resource development and maintenance. /36/ The ANRS regulation allows the resident water services to modify tariffs on local circumstances. Regarding to interviews with an employee of the Bahir Dar Town Water Supply Service Office, the institution does not get governmental support and is dependent on own income and external funding.
The mentioned unaccounted water ratio also indicates the missing data managing capabilities. An improvement is recommended and inevitable for improving water supply systems.

6.2.2 Water Sources

Replacing the Lake Tana and boreholes as water sources, springs are used for water supply. The Areke spring and the Lomee spring, located at 17 km and 17.8 km far from the centre of the town, provide water at a flow rate of 185 L/sec. Due to the good water quality marginal treatment is required at present beyond chlorination, which is one of the most common form of disinfection. /3/ The chlorine is added at the 2 pumping station of the springs. The springs seem to be adequate as water source and meet the demand for the coming years.

6.2.2.1 Storage Reservoirs

The mains from the Areke spring and the Lomee spring are merged into one and led into a main storage with a capacity of 2000 m^3. Combined with smaller storages there is a total capacity of 4500 m^3.

6.2.2.2 Water Quality

Monitoring and evaluating the quality of the supplied water is the duty of the Water Supply Service. Even though the source of the water is quite safe, the necessity of frequent monitoring should not be neglected. One of the disadvantages for the Water Service are missing laboratory facilities. However, some of the important facilities are available. Analyses of the water quality of the two springs show that the water is fresh and chemically within the recommended WHO limits. /38/

6.2.2.3 Water Tariff

The regulation No 15/2000 (19th of June 2000) of the council of the Amhara National Regional State set objectives concerning water tariffs. Some objectives compiled from the regulation are /38/:

- To enable towns to distribute potable water to the communities by covering their own cost for construction and repair free from government funding.
- To enable water and sewerage service offices to cover their operational and repair costs, and through time withdraw from government subsidy.
- Proper utilization of limited water resources and making potable water supply long lasting and clean drinking water available for the town's population.
- To implement tariffs based on the amount of consumption.

As mentioned above (6.2.1), the ANRS regulation allows flexible tariffs on water. Water tariffs in Bahir Dar are listed in table 9 below.

Table 9: Water Tariffs, Bahir Dar (2005)

Public fountain	Birr 1.25/m³	
Other connections	Birr 1.50/m³	0-5 m³
	Birr 1.75/m³	5.1-10 m³
	Birr 2.00/m³	10.1-25 m³
	Birr 2.25/m³	25.1-40 m³
	Birr 2.50/m³	>40 m³

The prices were listed in 2005, but the Water Supply Service Office confirmed the tariffs as current.

6.2.3 Sanitation Facilities and Waste Water Treatment

Only a few households in Bahir Dar have septic tanks (about 5 %), but about 67 % have access to pit latrines.
Table 9 lists numbers of access to sanitation facilities.

Table 10: Access to sanitation facilities in Bahir Dar, 2006 /36/

Facility	Households
flush toilets with septic tank	2000
own pit latrine (quite simple construction, lacking ventilation	2600
pit latrines, shared with e.g. neighbour	5400
communal latrine facilities	80 (app. 600 households Are dependent on these)

Other households with no access to sanitation facilities presumably use open fields or some other outdoor spots for urination/defecation directly or for disposing the liquid wastes. /36/ The liquid, but also solid, waste disposal system of the city has limitations in availability, such as missing septic tanks as well as road site waste bins.

There is no sewage system in the city and the city has only 2 vacuum trucks for dislodging and emptying the septic tanks. /38/ The waste is disposed off without proper treatment. /39/ The collection infrastructure is poor and treatment plants for the disposal of liquid waste are missing in Bahir Dar.

7. Conclusion

"Every human being on earth is a stakeholder in water resource management". (U. Aswathanarayana, 2001)

Future water management in Ethiopia, but also globally, is a sector that is increasing major concern. The current trends indicate that the situation of access to clean drinking water is alarming and the water scarcity is threaten 50 % of the population within the next generation. /2/ Since Ethiopia is a country that, as discussed in the thesis, suffer from economic water scarcity, an enhancement of management is inevitable, since institutional weakness prevents effective implementation of legal instruments for better water supply and quality control. Mismanagement and governmental failure result in significant degradation of both water quality and quantity. The awareness of a global water crisis does exist, but still not enough action is undertaken, which will have devastating consequences.
Several projects, reforms and assessments on economic and environmental impacts of the increasing water use in both developing and developed countries have been made and water management and its objectives – the use and reuse of water in an optimal, sustainable and equitable way – get more and more attention.
Partially high investment cost for technical equipment, development and waste water treatment are hard to justify especially in developing countries, but mainly there, the poor supply of safe drinking water and access to sanitation is resulting in water borne diseases and environmental impacts. The resilience of our ecosystems is limited and it is our duty to prevent a collapse.

The management of water, one of our scarce resources, requires understanding of hydrology, but nowadays also the awareness of rapidly growing populations and competing demands for water.
In Ethiopia, an intensive use of agricultural land, accompanied by inadequate water resource management, are leading to the degradation and depletion of water sources.

Referring to U. Aswathanarayana's quotation, that everyone is a 'stakeholder' in water resource management, everyone of us should be more conscious about the value of water and how dependent we are on this resource.

Water is life. Everyone does have the right to safe drinking water, either in developed or developing countries. Low level of awareness will be one of the major constraints.

Fig. 8: Leaking water pipe in a hotel bathroom, Bahir Dar 2009 /37/

Hence, one opportunity is the so called 'polluter pay' principle, or 'user pay' principle. Approaches have shown the reduction in both water use and pollution (especially in the industrial sector) in other countries. The principles stimulated changes in the attitude of water utilization and led to more recycling, reuse and improvements for clean processes in industry or agriculture.

Awareness creation is therefore inevitable. The improvement of the actual situation requires an increase in public, but also governmental, awareness of the problems. More access to information and participatory management could increase the behavioural changes by controlling individual water demands. Since most of the inadequate water use, and the consequential water loss, are mainly resulting from management problems, training of the responsible, to strengthen their function, but additionally the improvement of operations, maintenance and data recording systems are important.

The discussed recommended practices and the example of Bahir Dar show that there is a huge need to improve the situation in Ethiopia and, however, that there are potentials and opportunities in the country, that have to be put to account.

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