The Impact of the Irrigation System and Agricultural Production on Water Quality in Chókwé Irrigation Scheme

Thesis

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Bachelor of Natural Resources

Hyväksytty ___.___._____ ____________________________________

SAVONIA-AMMATTIKORKEAKOULU **OPINNÄYTETYÖ**
Iisalmen yksikkö **Tiivistelmä**

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Tiivistelmä:

Opinnäytetyön tavoitteena oli tutkia kastelujärjestelmän ja maatalouden vaikutuksia kastelujärjestelmässä virtaavan veden laatuun. Tutkittu alue sijaitsi Chókwén kylän ympäristössä Mosambikissa, eteläisessä Afrikassa. Kastelujärjestelmään kuului 28 600 hehtaaria viljelyksessä olevaa maata. Pelloilla viljeltiin pääasiassa riisiä, jota oli noin puolet alasta ja muita viljelykasveja kuten viljoja ja puuvillaa. Talviaikaan alueella viljeltiin pääasiassa vihanneksia. Opinnäytetyössä keskityttiin Mosambikissa sijaitsevaan Limpopo-joen jokialueeseen.

Tutkimme työssämme kuutta eri veden laatuun vaikuttavaa tekijää: nitraattia, fosforia, pH:ta, johtavuutta, sameutta ja liukoista happea. Lisäksi mittasimme myös lämpötilan, jota tarvitsimme tarkan pH-arvon määrittämiseen. Näytteenottopisteitä tuli kaiken kaikkiaan 98, joista käsittelemme työssämme 40. Tulokset analysoimme käyttämällä SPSS-ohjelmaa. Tutkimustuloksista on nähtävillä, että johtavuudella ja pH:lla on suurimmat erot kastelu- ja poistokanavien veden välillä. Nitraatti- ja fosforipitoisuuksissa sekä liuenneella hapella ja sameudella ei ollut tilastollista merkitsevyyttä. Nitraatti- ja fosforipitoisuudet olivat hyvin alhaiset, paljon alle Mosambikin kansallisten raja-arvojen.

Tämä työ on tehty yhteistyössä Universitade Eduardo Mondlanen ja Savonia-ammattikorkeakoulun kanssa osana verkostoyhteistyöohjelmaa, North & South Higher Education Programme. 2008 marraskuussa oli ensimmäinen neljän maan yhteinen (Mosambik, Kenia, Suomi, Etelä Afrikka) intensiivivesikurssi. Syksyllä 2009 on seuraava intensiivikurssi Keniassa.

Avainsanat:
Veden laatu, kastelujärjestelmä, maanviljely, Mosambik

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SAVONIA UNIVERSITY OF APPLIED SCIENCES **THESIS**
Iisalmi **Abstract**

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Abstract:

The main objective of this Thesis was to determine the impact of the irrigation system and agricultural production on water quality in an irrigation scheme. The investigate irrigation system was located in the village of Chókwé, Mozambique. The irrigation system extends up to 28 600 hectares of agricultural land area. Fields in Chókwé produce mainly rice (half of the area) and other crops (cereals, cotton) and mainly vegetables during winter time. In the Thesis was focused on the Mozambican part of the Limpopo Basin.

In our Thesis were measured six different water quality parameters: nitrate, phosphorus, pH, conductivity, turbidity and dissolved oxygen. In order to determine the exact pH- value the water temperature was measured, too. We investigated The samples examined in the Thesis were taken from 40 sites. All together there were 98 sampling sites. The measured data was analyzed by using the SPSS software. According to this research the most significant differences between the irrigation and the drainage canals occur in the pH-values and in the conductivity levels of the water. Nitrate and phosphorus concentration, turbidity and dissolved oxygen concentration seem to have no statistical significances. Nitrate and phosphorus concentrations are very low, below Mozambican standards.

This study is made in the cooperation with Universidade Eduardo Mondlane and Savonia University of Applied Sciences as a part of North&Shouth Higher Education Institution Network Programme. In March 2008 there was the first intensive course shared by four countries Mozambique, Kenya, Finland and South Africa. The next intensive course will be held in Kenya in the fall 2009.

Keywords:

Water quality, irrigation system, agriculture, Mozambique

Confidentiality:

Public

SUPPLEMENST

1 INTRODUCTION

1.1 Background

Many people think that Africa is a humid, tropical continent. In reality, 65% of the continent's land area is classified as arid or semi-arid. Six of the driest countries in the world are found in Africa and this number is expected to double by the year 2025. The majority of Africa's population live in the continent's tropical greenbelt, which includes the Congo River basin and the coastal forests in the west and east Africa, so the distribution of water resources is linked to the distribution of the people. The quality and quantity of water is a vital factor in determining the well-being of the population. The fact that the population is concentrated to the tropical greenbelt is also related to the availability of land suitable for cultivation. In the African continent, there is 0,7 ha of arable land per person, which is lower than in any other part of the world except Asia. (Atlas 2003, p.13.)

The shortages of arable land and water are made worse by Africa's rapid population growth, which is the fastest in the world. The population growth and poor economic performance have put increasing pressure on Africa's resources. People are forced to live in the marginal areas; urban settlements or semi-productive land. While the continent is economically dependent of agriculture, the agricultural loses are expected to increase in the future as farmers make the production more effective by using inappropriate farming practices that lead to soil erosion of cultivated land. (Atlas 2003, p.13.)

PICTURE 1. Local accommodations in Xilembene (Source: Liisa Pekonen, 2007)

River basins are the foundation of the link between land and water. Because water runs downhill, basins usually start at a top of a mountain where water starts to flow in different directions. Water running downhill forms a river or a stream, flowing above or below the surface, and usually flows to the sea. Throughout history rivers have been used as natural borders between countries and regions. Because rivers usually flow somewhere in the middle of the basins, many river basins are shared by two or more countries. Southern Africa has one of the most complex networks of international rivers and shared river basins and Mozambique is the extreme case, with nine international river systems. The Limpopo River basin is one of them. (Atlas 2003, p.16.)

PICTURE 2. Limpopo River (Source: Liisa Pekonen, 2007)

1.2 Objective

The main objective of this study was to research the impact of the irrigation system and agricultural production on water quality in an irrigation scheme. The goal was to determine impacts of the irrigation system on the environment and the source of the problem as well as the possible mitigation measures. The irrigation system which was investigated is located in Chókwé, Mozambique. The irrigation system extends to 28 600 ha of agricultural land area. Fields of Chókwé produce mainly rice (half of the area) and other crops (cereals, cotton) and mainly vegetables during winter time.

As far as we know there have been no published studies about the water quality in Limpopo River in Chókwé.

1.3 Scope

The field work was done during little over four weeks stay in the village of Chókwé, Mozambique. Chókwé is located about 220 km north from the capital city Maputo and about 100 km north-west from the city of Xai-Xai. In total, three months was spent in Mozambique to do the research and write the thesis. In the thesis, the focus was on the Mozambican part of the Limpopo River basin, also called as the Lower Limpopo.

Part of the irrigation water from the irrigation system in Chókwé is drained to an artificial lake and the rest goes straight back to the Limpopo River. The water samples were taken from 98 sites from the upper course and in different locations of the irrigation and drainage system. PH, water temperature, turbidity and conductivity were measured from these 98 sites. Nitrate, phosphorus and oxygen concentration were measured with the reagents from 34 sites. These sites were chosen among the same locations where the first 98 samples were taken. PH, water temperature, turbidity and conductivity were also measured from these sites again. The second time, 68 water samples were taken in total. Nitrate, phosphorus, pH, water temperature, turbidity and conductivity were measured from the last 34 sites. Oxygen levels could not be determined from the last points, because of the lack of reagents.

PICTURE 3. Main channel near the village of Chókwé (Source: Liisa Pekonen, 2007)

2 FACTS ABOUT MOZAMBIQUE

Mozambique is a long land on the shore of Indian Ocean. The land area in the Mozambique is 801 590 km^2, and there lived 20,9 million people in 2007. The capital of the Mozambique is Maputo which is in the southern part of the country. Mozambique has six lands as neighbours. The neighbouring countries are Malawi, Zimbabwe, South-Africa, Tanzania, Zambia and Swaziland. (The World Factbook, 2008) The official language is Portuguese but only 25% of townspeople and 12,5 of people in country speak it. In Mozambique there are many different religions. The most common religion is Catholics, 23,8% of population. Other religions are Zionist Christians 17,5% of population, Muslims 17,8% of population, other religions is 17% of population and those who have no religion is 23,1% of population. In year 2007 the life expectancy was for the females 40,4 years and for the males 41,4 years although the median age is only 17,4 years. (The world Factbook, 2007)

PICTURE 4. Map of Mozambique (Source: Anne Hakala.2008)

2.1 Facts about Chókwé

The village of Chókwé is part of the productive coastal zone (Bilene-Macia, Xai-Xai, Manjacaze, Chókwé, Guijá, and Chibuto) and it is suitable for agricultural production. The productive coastal zone has comparatively fertile soils and favourable climate. The main crops grown are maize, manioc, rice, fruits (castor beans, mango, and oranges), cashew, tobacco, cotton and sugarcane. The local markets in the coastal zone are fairly well developed and accessible. Poor households manage to produce 50 – 60 percent of their basic food needs. The rest of the income comes from the sale of crops, animals and local beer, working as a labourer, donations or remittances from family members or friends working in South Africa. (Louw and Gichuki, 2003. p.35.)

PICTURE 5. Part of the irrigation system in Chókwé (Source: Liisa Pekonen,2007)

2.2 Facts about Universidade Eduardo Mondlane

The Universidade Eduardo Mondlane (UEM) is the oldest and largest university in Mozambique. The UEM is situated in the heart of Maputo, the capital of Mozambique. At present, about 8000 students study in the UEM. The institution was founded as a centre for higher education in 1962. Back then Maputo was called Lourenço Marques and it was the capital of Portugal´s province of Mozambique and the newly founded education centre was called Estudos Gerais Universitários de Moçambique (Mozambique General University Studies). In 1968 the name was changed to Universidade de Lourenço Marques (University of Lourenço Marques). Mozambique gained independence in 1975 and the capital city was renamed Maputo. The University of Lourenço Marques was renamed in honour of the leader of the Liberation Front of Mozambique (Frelimo), Eduardo Mondlane. (UEM, 2007)

3 CHARACTERISTICS OF LIMPOPO RIVER BASIN

3.1 Geography

The Limpopo basin is shared by four different countries; Botswana, Zimbabwe, Mozambique and South Africa. The total length of the main river is about 1,750 km and it is located between latitudes 22°S - 26°S and longitudes 26°E - 35°E. The total surface area of the basin is about 412,938 km^2, from which 44% is occupied by South Africa, 21% by Mozambique, almost 20% by Botswana and 16% by Zimbabwe.(Louw and Gichuki, 2003. p.2.)

PICTURE 6. Limpopo River from Macarretane dam (Source: Anne Hakala, 2007)

The Limpopo River starts at the confluence of the Marico and Crocodile rivers in South Africa to the north-west of city of Pretoria and is joined by the Notwane branch at Buffels Drift. The Limpopo forms the border between Botswana and South Africa and it flows in a north-easterly direction. At the confluence with the Shashe River, which flows in from Zimbabwe, the Limpopo almost turns due east and flows along the border between Zimbabwe and South Africa. For nearly 900 km, the Limpopo marks the international border between South Africa and its neighbours, Botswana and Zimbabwe. Then it enters Mozambique at Pafúri, at the point where Zimbabwe, South Africa and Mozambique meet. For the next 561 km the river flows within Mozambican borders before entering the Indian Ocean approximately 60 km downstream of the town of Xai-Xai. (Louw and Gichuki, 2003 p.4.) The Limpopo river basin significantly narrows in the coastal zone. The river course meanders about 70 kilometres through its lower valley, from the Xai-Xai town to the sea. The alluvial valley, which is formed within the inland, has a circular shape with a diameter of about 15 kilometres. The Limpopo reaches the Indian Ocean cutting the coastal dunes belt by narrow river mouth. Typical river-ocean interrelations are in a relatively small coastal and marine area. (Louw and Gichuki, 2003. p.44.)

Picture 7. Limpopo River Basin (Source: Anne Hakala, 2008)

The Limpopo River basin is divided into three sections; the Upper Limpopo, the Middle Limpopo and the Lower Limpopo. The Upper Limpopo goes from the headwaters down to the Shashe River confluence at the South Africa-Botswana-Zimbabwe border. The Middle Limpopo is located between the Shashe confluence and South Africa-Zimbabwe-Mozambique border at Pafúri and the Lower Limpopo flows downstream of Pafúri to the mouth of the river on the Indian Ocean. (Atlas 2003, p.22.)

The Limpopo basin is made up of many sub-basins and tributaries. The Crocodile River is the largest of the Limpopo tributaries, draining an area of 26 900 km^2. The Elefantes, called the Olifants within South Africa, and its tributaries form the largest sub-basin of the Limpopo with an area of 79,000 km^2, of which 84% is located in South Africa. The Elefantes and its tributaries bring the most water to the Limpopo River. Another large sub-basin, the Changane, with an area of 43,000 km^2, exists entirely within Mozambique, but this tributary has a very low run-off. (Louw and Gichuki, 2003. p.4.)

The total annual flow from the basin is approximately 5.5 x 10^9 m^3 per year. There are lots of annual variations in the flow of the Limpopo. Characteristics of the Limpopo are very low flows during the dry season, which causes severe droughts, and flooding during the high wet season. The river is not perennial in all years and in some years is dry for several months. It is estimated that only 10% of the measured flow at Chókwé is generated within the Mozambican part of the Limpopo basin. (Louw and Gichuki, 2003. p.33.)

3.2 Topography and landscape

Plains are the dominant landform of the Limpopo basin. The western 2/3 of the basin is a part of the continental plateau and the eastern 1/3, wide coastal plain. The basin consists mainly of terrain between ranges of low gradient hills, valleys and medium gradient mountains. The Waterberg plateaus on the south and Soutpansberg Mountain range in the north-east are the main topographic features in the basin. The South African highveld forms a high-lying rim in the south. The Mozambique portion of the basin consists of terrain with numerous small tributary streams and pools forming part of the Changane drainage system. There is a belt of heavy textured soils connecting Limpopo to Incomati river system which suggests that the Limpopo previously also discharged to the Indian Ocean from Maputo Bay. (Louw and Gichuki, 2003. p.3.)

Because of the changes in elevation along the Limpopo and the Elefantes, the Mozambican part of the Limpopo Basin is very vulnerable to flooding. The Limpopo River's headwaters start 1000 meters above sea level, but the rivers drops sharply before entering Mozambique at only 200 meters above sea level. After another decent near Pafúri, the Limpopo flows its final 400 km at elevations of less than 100 meters in the flood plains of Mozambique. The final 175 km Between Chókwé and the river mouth are at elevations less than seven meters above sea levels. The Elefantes River, although only half the length of the Limpopo River, has much steeper drop in elevation with a sharp drop from 1500 meters to 80 meters within distance of 700 km. (Atlas, 2003. p.21.)

Most of the Limpopo Basin area (82,5%) is dry land cover conditions. Only small percentage of the land is irrigated (0,9%) or wetland ecosystems (2, 8%). 26,3% of the basin is non-irrigated cropland. High value crop production under irrigation includes sugarcane, citrus and bananas. Over the last 60 years the basin has lost 99% of its original forest cover and nowadays the forest land cover is only 0,7% of the basin. Rest of the rural area of the basin is savannas, grasslands and scrublands (67,7%), with their splendorous Boabab trees. (Louw and Gichuki, 2003. p.29.)

PICTURE 8. Papaya (Source: Liisa Pekonen, 2007)

Conservation areas of Botswana and the Mashatu game reserve are situated in the Limpopo basin. The Limpopo Transfrontier Park dominates the central areas of the basin. (Louw and Gichuki, 2003. p.29.)

3.3 Climate

The climate of the Limpopo basin varies from being arid in the west through semi-arid and temperate areas in central zones to semi-arid in the east, with a few sub-humid pockets in the centre. (Louw and Gichuki, 2003. p.4.) The coast of Mozambique is influenced by the southward-flowing Mozambique current that brings warm water and humid air from the Equator and produces a humid, warm climate. The western coast of the southern Africa is influenced by the cold Benguela current from the Atlantic Ocean and in the interior of southern Africa where Limpopo basin is located; there is a strong gradient from east and west. (Atlas, 2003. p.17.)

Rainfall varies dramatically across the basin, from over 1000 mm per year in the eastern highlands to less than 300 mm per year in the arid central regions of the basin. The majority of the basin receives less than 400 mm rainfall per year. Throughout most of the basin, annual rainfall totals are very variable and distribution of rainfall within the season is most irregular. The most of the rainfall occur as thunderstorms during the summer period. Approximately, 95% of the annual rainfall occurs between October and April, often with a dry spell during critical periods of crop growth. A short and intense rainy season, with a very unreliable rainfall, leads often to droughts. Rainfall also varies significantly between years. (Louw and Gichuki, 2003. p.4.)

PICTURE 9. Storm is rising in the Limpopo Basin (Source: Liisa Pekonen, 2007)

Summers are generally warm and winters mild. Air temperatures across the Limpopo basin show a seasonal cycle, with highest temperatures recorded during the early summer months and lowest temperatures during the cool and dry winter months. The maximum daily temperature over most of the basin area ranges from 30-34°C during summer and 22-26°C in the winter. The minimum daily temperature in most areas ranges from 18°C to 22°C in summer and 5°C to 10°C in winter. Most high-lying areas of the Basin experience frost, which is most severe in the south-western part of the Basin. Frost creates an occasional problem for late-planted crops. (Louw and Gichuki, 2003. p.6-7.)

The Mozambican part of the Limpopo Basin, the Lower Limpopo, consists of three major climatic zones:

a) The coastal Xai-Xai zone in the lower portion of the region and its connection to the sea.

b) The Lower Limpopo Valley (including the Chókwé area), which is situated in the area between Xai-Xai and the Macarretane Dam.

c) The Upper Limpopo Valley, which is the area from Macarretane Dam up to the Mozambican border. (Louw and Gichuki, 2003. p.7.)

3.4 Geology

The geology of the Limpopo basin presents the geological history of the whole African continent. Igneous and metamorphic rocks found in the upper basin date back as far as to the Precambrian Era (3,400 million years) and are some of the oldest in Africa. These rocks are part of the crystalline basement complex which lies under the continent. Thin veneers of younger terrestrial deposits from the Permian (290 million years) and Triassic (240 million years) Eras overlay the basement complex in several places in the upper basin and younger Mesozoic igneous rocks have become exposed because of erosion. (Atlas, 2003. p.23.)

The bedrock of the central region of the basin is granite gneiss and migmatite. To the north, in Zimbabwe, the dominant rock is shale, and granite in the north of Gwanda. (Louw and Gichuki, 2003. p.7.) Minerals and salts consumed from the upper reaches of the basin have an impact to the water and poor water quality in Mozambique. (Atlas, 2003. p.23.)The mineral rich Bushveld igneous complex extends across the south-eastern part of the basin, and precious metals are mined at various localities throughout the area. Large coal deposits are found in the north-west. Sandy surface deposits occupy the far western edge of the Basin. The coastal plain is dominated by the Mananga deposits. The basin has extensive mineral deposits and mining activities in the South Africa part of the basin are very important. (Louw and Gichuki, 2003. p.7.)

Soil plays a crucial role in run-off of surface water that contributes to flooding. Since the soil soaks up as much rain water as possible before releasing the rest as surface water, the soil texture determines how much water it can hold after rainfall. Higher water holding capacity is typical of clay soils that can create a barrier to water drainage and hold the water long after the rain. Sandy soils have low water holding capacity and run-off of surface water is unusual because the water penetrates the soil quickly. Loamy soils are in between clay soils and sandy soils; they hold good amount of water without becoming water-logged, and so good for the agricultural purposes. (Atlas, 2003. p.24.)

The dominant soil types in the basin are moderately deep sandy to sandy-clay loams in the south, grading to shallower sandy soils in the north and deeper sandy soils in the west and east.

a) Arenosols (sands, not highly weathered) cover the Mozambique coast, in a zone next to the Lebombo range, and in the southern half of the Botswana part of the Basin.

b) Solonetz soils (sodium affected soils) cover most of the Mozambique coastal plain.

c) In Zimbabwe and the northern parts of the Botswana parts of the Basin, there are mainly Luvisols (soils with a clay increase, not highly leached) and Leptosols (shallow soils).

d) In the South African part of the Basin, Regosols (weakly developed soils) dominate between the eastern escarpment and the Lebombo range. Much Leptosols occur wherever there is hilly terrain.

e) The highveld of the southern Basin is dominated by Acrisols (soils with low CEC and low base status). A few extensive areas of black vertisols in the southern parts of the basin support important agricultural developments. (Louw and Gichuki, 2003. p.7-8.)

PICTURE 10. Ordinary road in irrigation system (Source: Anne Hakala, 2007)

The deep loam soils are crucially important for agriculture and support extensive irrigation developments along many tributary rivers in South Africa, such as the Crocodile River region. Layers of wind-blown Kalahari sands cover large areas of the western section of the Limpopo basin, while the sandy soils of the eastern (Mozambican) section are derived from old marine sands. These sandy soils support important hardwood timber resources. (Limpopo River Basin Factsheets, 2007)

The valley bottom soils along the tributary rivers of Limpopo and the main channels of Limpopo are in general originally colluvial or alluvial and support extensive areas of agriculture. There are also some hilly or steeply areas which have stony soils with little agricultural potential. (Limpopo Basin Fact Sheets, 2007)

3.5 Hydraulic infrastructure

The waters coming downstream from the South African highveld have been captured by dams to support the area's economic development and urbanization. There are at least 13 dams with a storage capacity exceeding one km^3 in the basin area. One is located in Mozambique, eight in South Africa, three in Zimbabwe and one in Botswana. The largest is Massingir dam in Mozambique whose present capacity of water flow is about 1.2 km^3. There are also many smaller dams in the area which have very little storage capacity. Dam management can be enhanced in the future to control water control and mitigate the impact of drought and floods. (Limpopo River Basin Factsheets, 2007)

PICTURE 11. Macarretane dam (Source: Liisa Pekonen, 2007)

At present, there are just two hydraulic structures which store water within the Lower Limpopo Basin: the Massingir dam and the Macarretane dam. The Massingir dam, as it exists now, is not operating to its full potential because of serious leakage and structural shortages on its walls and gates. There are plans to start the rehabilitation of the dam and its downstream irrigation structures for agriculture. (Louw and Gichuki, 2003. p.37.) If and when the Massingir dam is fully rehabilitated to operate at its designed capacity, it should be able to provide enough water from the Elefantes tributary which together with the water flowing from the upstream of the Limpopo River will be able to irrigate the irrigation schemes in the middle and lower portions of the Limpopo Basin. (Louw and Gichuki, 2003. p.38.)

3.6 Demography

In the area of Limpopo river Basin, live more than 14 million people. The Basin has a strong diversity of rural versus urban population. Within or near the Limpopo Basin boundaries there are many urban population centres. Aside those big cities, Limpopo Basin is predominantly rural. (Louw and Gichuki, 2003. p.15-16.) Rural population density is less than half in South Africa than other countries in the Basin. It has only 10% of its total labour force in agriculture, which is the lowest in the Basin region, although the Limpopo Province is overwhelmingly rural and least-developed in South Africa. In the Limpopo Basin area the women contribute more to the agricultural labour force than men, with the exception of South Africa. (Louw and Gichuki, 2003. p.17.)

PICTURE 12. Women peeling the cow beans (Source: Anne Hakala, 2007)

The demographic characteristics, the size of the population, its growth rate, density, and rural/urban distribution has strong bearing on basin-wide productivity and livelihood security outcomes. Among the countries within the basin, South Africa has the largest population, while Botswana has the smallest. The population density varies from 3 people/ km^2 in Botswana to over 33 people/km^2 in South Africa and Zimbabwe. During the last two decades, population density has increased in all countries within the Basin, although population growth has started to slow down in recent years.

Because of the high HIV/AIDS infection rates, the population in the Basin region has a very low life expectancy, especially in the poor rural communities. If the infection rates do not decrease, they are likely to reduce the future workforce and increase dependency ratio. This would have extensive welfare impacts especially for children, economically inactive and older people. (Louw and Gichuki, 2003. p.16.)

PICTURE 13. Traditional agriculture (Source: Liisa Pekonen, 2007)

4 IRRIGATION SYSTEMS

At the worldwide scale 278,8 million hectares are irrigated land. Most of the irrigated area locates in Asia (68%) where in America the irrigated area is approximately 17%. In Europe the total irrigated area is about 9%, in Africa approximately 5% and in Oceania about 1% of total cultivated area. About 18 % of the world's cropland is irrigated, producing 40 % of all food grown. Irrigation uses globally some 70% of all waters in the groundwater and rivers. (Siebert *st al*, 2000)

PICTURE 14. Irrigation channel (Source: Anne Hakala, 2007)

4.1. Surface irrigation

Most of the irrigation systems in the world are implemented in **a surface irrigation** method. There are several different surface system methods like basin, furrow and border irrigation, contour ditches and water spreading. The contour ditches and the water spreading methods have little if any interest and these methods are mainly used to irrigate pastures. (Pereira, 1999)

4.2 Basin irrigation

Basin irrigation method is the most used irrigation method in the world. This irrigation method is used mostly for rice and other crops and also orchard tree crops. In the basin irrigation system water surface is levelled to basins. In the basins there are perimeter dams which allow the infiltration after the cut off and prevent the runoff. The best implementation can be obtained when non-erosive discharges are used which minimise the advance time and when the surface of the basin is strictly levelled. Usually the basins are not even, quite small and the utilization of the water in the basins is controlled manually. In the few developed countries laser-levelled basins are used which have a manual or automatic control system. (Pereira, 1999)

4.3 Furrow irrigation

In the **furrow irrigation** systems field has to be a bit slope. Stream velocity of the water is low which makes the water infiltration better when water flows down to the field. Low water flow also makes less runoff losses but too low stream velocity causes infiltration excess in the upper part of the field. In the developed countries, where the control of water is automatic or semi-automatic, furrow systems are becoming more common. Those systems are precisely levelled and long. In the traditional irrigation most commonly used are short blocked furrows where the water is manually controlled. (Pereira, 1999)

4.4 Border irrigation

In the **border irrigation** system water is derived to long or short channels. Channels are banked on both sides and the channel is open at the downstream end. The irrigation takes place when the water advances, flows in the channel and infiltrates along the borders. In the border irrigation method applied automatic water control systems are usually used. When the rake of field is very small a larger inflow is used. Then the control of water becomes identical to basins. (Pereira, 1999)

4.5 Traditional systems

Traditional irrigation systems are often used in border irrigation systems, small basin irrigation systems and short furrow irrigation systems. The traditional irrigation systems are mostly used manually. In the traditional system it is not easy to control the amount of water because the water flow is often unknown and very variable. The fields are also usually very grainy which makes it more difficult to control the amount of the water. Because of those difficulties each irrigation system has many different variations of stream velocity. The stream velocity often escalates and causes over irrigation. (Pereira, 1999)

4.6 Modernised systems

Modernised irrigation methods are different from traditional irrigation systems because in them the management of water flow is possible. In these modernised irrigation systems automatic channel gates and partitions are used. The forms of flow management are such as gated pipes, siphons and lay-fat tubes. In most of the cases the fields are exactly levelled. Under these circumstances incoming flowing can be estimated or surveyed. (Pereira, 1999)

4.7 Sprinkler irrigation systems

Sprinkler irrigation systems are popular among farmers because in this system they can control the flowing rates, frequency and a running time better than for example in surface irrigation systems. Usually sprinkler systems are implemented in two different ways. One way is that a sprinkler system is connected to some networks which are usually operated on demand. In some of the sprinkler irrigation systems the water is distributed independently. There are many different sprinkler irrigation systems like solid set system where the sprinkler irrigation system is in fixed position. Other sprinkler systems are hose-reel, hose-bull and travelling guns where depth ranging of irrigation can be applied from 15 mm to 40 mm. The last of he sprinkler irrigation methods are continuous move laterals which are used in a frequent and small irrigated areas. (Pereira, 1999)

4.8 Irrigation system in Chókwé

The irrigation scheme in Chókwé is the largest irrigated area within Mozambique. Its length is more than 50 km and it is 2 to 15 km wide alongside the right bank of the Limpopo River. The scheme was established in the 1950s and it was designed to irrigate 30 000 ha of agricultural area. At present, the irrigation system stretches on the area of 28 600 ha but only 22 800 ha is arable land. The Chókwé irrigation system is irrigated with the border irrigation system. The whole irrigation network is supplied by gravity drainage. (Louw and Gichuki, 2003. p.38.) The Chókwé irrigation scheme used to produce rice on nearly 20 000 ha. The scheme was damaged severely in the floods in 2000 and the range of rice fields has been reduced to 3000-4000 ha in recent years. (Atlas 2003, p.36.)

PICTURE 15. A small hydraulic structure in an irrigation channel to control water discharge (source: Liisa Pekonen, 2007)

The River Limpopo is the second largest river in Mozambique after the Zambezi River but it is the most crucial agriculturally because it has the largest irrigation scheme in the country. Given the very unsteady and erratic rainfall conditions in most parts of Mozambique, and the Limpopo River Basin in particular, the water in the Limpopo River as a resource for agricultural production activities is very important. (Louw and Gichuki, 2003. p.37.)

Under the Mozambique Water Act, water is considered as a public good and there is no private ownership of the water. Individuals, communities, water supply companies and private enterprises need a license to abstract surface or groundwater. Licensing is not required for using water in small quantities, which is the case for the great majority of the rural communities. The licenses are issued by National Directorate of Water, and it can delegate this function to the regional water authorities. (Louw and Gichuki, 2003. p.28.)

4.8.1 Problems in irrigation systems in Chókwé

Within southern Africa, Mozambique historically has been most affected by natural disasters like drought, floods and cyclones. These disasters have significant human agricultural, infrastructural and economical impacts. The Limpopo basin, including Chókwé area, is one of the most risk prone areas in a highly risk prone country. (Atlas 2003, p.7.)

PICTURE 16. Drought prone land (Source: Anne Hakala, 2007)

The Limpopo basin does not have many substantial dams to regulate its flows unlike the country's largest river basin, the Zambezi. Most of Mozambique's portion of the basin lies at elevations of less than 1000 meters above sea level and heavy rains in South Africa, Botswana and Zimbabwe flow directly in the lowlands of Mozambique. (Atlas 2003, p. 7.) Floods can be highly destructive but they are also a natural part of the ecological cycle because flooding add nutrients to the soil replenish underground alluvial aquifers and creates large fish and crop yields. The positive and negative consequences of flooding can change depending on the magnitude, speed and duration of the flood. (Atlas 2003, p.11.)

Cyclones are the rarest, but deadliest, problem facing the people and agriculture in the Limpopo basin. The basin lies outside the major tropical cyclone zone but sometimes cyclones do affect the basin area directly. Heavy inland rain, brought by cyclones, can cause serious flooding in the Limpopo basin area and in the irrigation system. (Atlas 2003, p.7.)

Floods and cyclones are not the only hazard that causes problems in the Mozambican part of the Limpopo basin and in the Chókwé area. Most of the basin receives less than 500 mm of rainfall in a year so of all the natural hazards affecting the area, drought is the most common and devastating.

Drought is not as dramatic hazard as flood or cyclones but it lasts longer, affects more people and causes more long time damage. (Atlas 2003, p.7.)

Pollution can be a problem in agriculture; fertilizers, pesticides, herbicides, animal waste, salts from evaporated irrigation water and silt from deforestation flow into ground and surface water and pollutes the water. Where return-flows are measurable, pollution of the water seriously deteriorates the value of the water. (Louw and Gichuki, 2003. p.34.)
The problem with the salt in the ground is also partly due to the salinity brought downstream from the poorly drained Chókwé irrigation scheme and also by salt coming from the Changane river tributary which passes through saline soils of the Changane Basin. (Louw and Gichuki, 2003. p.40.) The waters of the Limpopo are usually highly mineralised because the river drains a large catchment with a substantial part situated in an arid zone. High salinity of the water in the Lower Limpopo might increase in the future because of the construction of dams both within and outside Mozambique. If no consideration is given to the issue of water quality, this may have such a significant effect to which water can be used for irrigation. (Louw and Gichuki, 2003. p.43.)

PICTURE 17. Local women washing the laundry in the irrigation channel (Source: Liisa Pekonen, 2007)

Over-irrigation is a widespread problem in the Chókwé area and it causes nutrient leakage and waste of water. Water wasted through over-irrigation and poor irrigation efficiencies is lost to the whole system. Poor state of the irrigation structural network at Chókwé and elsewhere downstream also leads to substantial waste in irrigation water available in the system. The unit of consumption of water in the Chókwé irrigation system, which is estimated at 30,000m^3/ha/year, is currently too high by Mozambican or any other standard. (Louw and Gichuki, 2003. p. 37.)

Irrigation schemes rehabilitation and management, financial problems in irrigation, flood control management, water and soil salinization and drought are perhaps the most serious problems affecting agriculture in the Lower Limpopo area. (Louw and Gichuki, 2003. p.40.)

5 DESCRIPTION OF WATER PARAMETERS

5.1 Temperature

Temperature is measured with thermometers. Celsius (°C) and Kelvin (K) scales are the most commonly used in the temperature measurements. The Celsius scale was originally determined by marking the freezing point of clean water with zero and the boiling point with 100. There is also the Fahrenheit (°F) scale which is especially used in the United States. (Kroemer & Kittel, 1980)

The higher the water temperature, the greater the biological activity is in water. Fish, aquatic insects, zooplankton and other aquatic species all have a range of water temperature they prefer. As the water temperature gets too warm or cold for the species, individuals decrease until finally there are few, or none. Temperature is also important because of its impact to the water chemistry. Chemical reactions increase in higher temperatures and this has an impact for example to the oxygen levels in the water. Warmer temperatures increase the solubility of salts but decrease the solubility of gasses in water so warm water holds less oxygen that cool water. In warmer water there are also more toxic compounds for the aquatic life. (waterontheweb, 2007)

5.2 Electrical conductivity

Electrical conductivity (μS) is a measure of how well the material is conducting electrical current. Electrical conductivity of a solution can be considered as an indicator of the purity of the solution. Most solutions do not conduct electricity well when they are completely pure. Dissolved substances, for example salts and acids, make the solution conductive. (Oulun yliopisto, 2007)

Electrical conductivity reacts to temperature changes and increases with increasing temperature. In oceans, lakes and rivers the electrical conductivity is important because aquatic organisms need a relatively constant concentration of the major dissolved ions in the water. If the electrical conductivity gets too low or too high it effects the survival, growth and reproduction of the aquatic life. (Duluth Streams, 2008)

5.3 pH

pH-value shows how acidic or alkaline something is. pH is dependent upon the activity of hydrogen ions in the substance. At higher pH, there are fewer free hydrogen ions, and that a change of one pH unit reflects a tenfold change in the concentrations of the hydrogen ion. pH-value is usually between 0-14. Aqueous liquids with a pH-value less than seven are considered acidic and those with pH-value greater than seven are considered basic. Liquid is neutral when pH-value is exactly 7. Acidity is measured with a pH-meter or special colorants aka indicators, which change color according to the pH-value. (waterontheweb, 2007)

The pH of water defines the solubility and biological availability of chemical components such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). For example, pH can affect the amount of phosphorus in the water and in what form it is but it can also determine whether aquatic life can use it. In the case of heavy metals, the degree to which they are soluble determines their toxicity. Metals can be more toxic at lower pH because they are more soluble. (waterontheweb, 2007) In some cases the high pH-level can indicate powerful algae production. Especially in the summer the photosynthesis of the algae can increase the pH- level to substantially high. (Suomen ympäristökeskus, 2006. p.44)

5.4 Turbidity

Turbidity (FAU) is a measure of the degree to which light is scattered by suspended particulate material and soluble coloured compounds in the water. It provides an estimate of the muddiness or cloudiness of the water due to clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, plankton, and microscopic organisms. The water can be darkly stained from dissolved organic material which usually comes from bogs and other wetlands. Turbidity is often measured with an optical instrument called a turbidimeter. (Duluth Streams, 2008)

Turbidity in the water is a natural part of all streams and even the clearest of rivers run sometimes muddy, at least during the high flow. Although turbidity is a normal occurrence, too high sediment levels can cause problems in the water. Increased turbidity affects the river and the organisms that live in it. If the water becomes too turbid, the light underwater decreases which causes damage to the aquatic vegetation, algae and mosses which grow on photosynthesis. This also affects the herbivorous organisms such as snails, insects and fishes which feed on the aquatic vegetation. As a result of the slow photosynthesis, less oxygen is released into the water and the plants may even die. Because of the darker colour of the water, it gets warmer which also decreases oxygen. Fine particulate sediments can also have mechanical effects, such as clogging sensitive fish gills and organic material settled to the bottom may suffocate newly hatched larvae. (Duluth Streams, 2008)

5.5 Nitrates

Nitrogen (NO_3) exists in water in many forms, as solute molecular nitrogen, easily degradated organic substance, slowly degradated humus compounds or as inorganic compounds like ammonium, nitrites and nitrates. Nitrate is an outcome of a perfect nitrification process. In the nitrification process micro-organisms, for example the bacteria in the soil cause the oxidation of ammonium to nitrate. The nitrification in the soil produces nitric acid which causes acidification of the soil. Nitrogen fertilization of the fields can cause high concentration of nitrogen in the ground water. (Suomen ympäristökeskus, 2006. p.43.)

Green plants, algae and waterside vegetation use nitrates and this is one of the main processes in the productive layers of the water. The concentration of nitrates varies a lot in the natural waters being the lowest during the end of summer when the vegetation is plentiful. Nitrate concentration can be an indicator of the condition of the water. (Suomen ympäristökeskus, 2006. p.43.)

5.6 Phosphorus

Phosphorus (PO4) is a pluralistic non-metal which is usually found as an inorganic phosphate in every cell. In the nutrient cycle phosphorus travels from one organism to another. When the organism dies, the decomposers release phosphorus back to the inorganic ion form. Part of the decomposing happens at the productive layers of water, where the nutrients are reusable right away. Some of the decomposing happens at the bottom, where the released inorganic phosphate compounds get attached to iron as an insoluble compounds. When there is oxygen present phosphorus-iron compounds stay at the bottom layers. If the oxygen concentration close to the bottom is low, compounds dissolve to the water and are released back to the nutrient cycle. (Tyystjärvi-Muuronen, 1985. p.11.)

Phosphorus is the key nutrient which influences plant growth in lakes and rivers. Too much phosphorus in the water causes eutrophication. The amount of phosphorus in solution that is available to plants is called soluble reactive phosphorus. Total phosphorus includes the amount of phosphorus in solution and in particulate form. (waterontheweb, 2007) Total phosphorus concentration is one of the most essential parameters of quality of water. (Suomen ympäristökeskus, 2006. p.43.)

5.7 Oxygen concentration

One of the most important sources of dissolved oxygen (DO) in water is oxygen in the atmosphere that dissolves to the water at the water surface.

The concentration of oxygen in the air is about 20%. (Connell, 2005. p.301.) In turbulent water conditions the water is well mixed and the concentration of dissolved oxygen is constant from the surface to the bottom waters. Thermal stratification, due to solar heating of the surface water, leads to the isolation of the bottom waters. If there is a lot of organic matter in the hypolimnion, the bottom layer of the water, and bottom sediments, the bottom waters may be depleted in dissolved oxygen, while the surface layers remain rich in oxygen. In this manner, there can be considerable variation in dissolved oxygen in the vertical profile of the water. Vertical stratification often occurs in a seasonal pattern. (Connell, 2005. p.304.) Oxygen deficiency is fatal to many aquatic animals such as fish, and to many kinds of anaerobic bacteria. (Manahan, 2000. p.63.)

6 WATER QUALITY DIRECTIVES AND STANDARDS

6.1 European Water Framework Directive

Water Framework Directive was established in year 2000. It is a directive which requires the reinstatement of biological classification criteria. From the year 2005 European Union has set a decree for the prevention of water pollution. (Suomen Ympäristökeskus, 2006 p.3.) Water Framework Directive provides that the surface waters have to be classified by types according to water formations and their catchments' natural geological, physical and chemical factors. (Suomen Ympäristökeskus, 2006 p.11.)

6.2 System of classification of rivers in Finland

From the 1970's Finland has used the system of classification of rivers to help planning of how to protect water systems. The classification of usability of waters has been made to help the system of classification of rivers. The classification of usability is based on the water's physical and chemical characters, hygiene's indicator bacteria and concentration of harmful substances. The European Water Framework Directive is going to change the classification of surface waters. The classification is going to be based on the water systems ecological situation and it is based on the biological quality substances: phytoplankton, aquatic plants, zoobenthos and fishes. Other biological parameters are going to be environmental standards of harmful substances, quality of water, hydrological and morphological factors. (Suomen ympäristökeskus, 2006 p.22.)

Classification of the surface waters according to the Water Frame Directive is evaluated by the effects of the human functions on the waters biological physical and chemical characteristics. In the classification of the surface water there are four different phases: to specify the comparison conditions of each type, to specify the class limits for the classification factors, to specify the differences between quality factors and quality parameters and to specify the classification of ecological situation. (Suomen ympäristökeskus, 2006 p.22.)

6.3 Water quality standards of Mozambique

PICTURE 18. Main channel close to Macarretane dam (Source: Anne Hakala, 2007)

In Mozambique there are specified standards for the drinking water, effluent discharges and for receiving waters. In the following table you can see the standards for dissolved oxygen, pH, nitrates, phosphate, total dissolved solids and turbidity.

Table 1, Water quality standards of Mozambique. (Chilundo, 2007 p.93, 94, 95.)

Subject	Chemical Symbol	Effluent discharges (Maximum allowable)	Receiving waters (Allowable values)	Drinking water (Maximum allowable value)
Turbidity	FAU	No value	No value	<5
Nitrates	NO_3	No value	10 mg/L	50 mg-/L
Dissolved Oxygen	D0	No value	>6 mg/L	No value
Phosphate	PO_4-P	3 mg/L	No value	No value
Total Dissolved Solids	TDS	No value	No value	1000 mg/L
pH		6-10	No value	6.5-8.5

7 METHODS

7.1 Equipment

pH-value from all the sites was measured with the equipment from the Savonia University of Applied Sciences. The conductivity was measured with the equipment which was borrowed from the UEM. The temperature meter was also borrowed from the UEM. Other measurements were taken with a Hach portable colorimeter which is owned by Iisalmi town. Reagents for the portable colorimeter were received from Hach’s outlet in South Africa. Reagents were ordered for one hundred samples. For measuring the oxygen concentration there were reagents for 50 samples but only 34 of them could be used, because the rest were reserved for another research. Disposable droppers, a bottle brush, scissors and disposable rubber gloves were also needed and they were brought from Finland. Distilled water and the containers to collect the water were received from the UEM.

7.1.1 Hach’s Portable Colorimeter DR/850

In the research, phosphorus, turbidity, nitrates and dissolved oxygen were measured using Hach’s Portable Colorimeter DR/850.

Table 2. Used programs of Hach's Portable Colorimeter. (Hach Datalogging Handbook p. 181-182, 207-208, 215,216, 229.)

Method	Program	Reagent/reagents	Sample/ mL	Time
Diazotiza-tion Method	60	NitriVer 3	10 mL	~17 min
Absorpto-metric Method	95	No reagent	10 mL	~3 min
HRDO Method	70	Accu Vac Ampul	50 mL	~4 min
Amino Acid Method	85	Molybdate reagent, Amino Acid Reagent Solution	25 mL	~12 min

PICTURE 19. Hach's portable colorimeter (Source: Liisa Pekonen, 2007)

7.1.2 pH 340i/SET meter by WTW

pH was measured using pH 340i/SET meter by WTW. The meter was calibrated before starting the measurements. The calibration was done using buffer solutions pH 7 and pH 4. After every sample the electrode was cleaned with distilled water. The meter was calibrated approximately after

50 samples. Only the temperature of the sample had to be set to the equipment.

7.1.3 Palintest* Micro 500 Conductivity meter

Conductivity was measured using Palintest* Micro 500 Conductivity meter. The equipment was borrowed from the UEM. After every sample the measuring stick was cleaned with distilled water.

PICTURE 20. Conductivity and pH meter (Source: Liisa Pekonen, 2007)

7.2 Practical details

The sites were reached by all-terrain vehicle. The water samples were taken to a 500 ml sample container which was tied to about 20 meter long cord. With the cord it was possible to get the water samples from as close to the middle of the canal as possible. Some of the samples were taken from a bridge that went over the canal and some were taken from the bank of the canal. A map of the irrigation system was available and so it was possible to plan samples beforehand. As it turned out, the map was not that accurate and some of the points had to be changed on the spot.

PICTURE 21. All-terrain vehicle (Liisa Pekonen, 2007)

On the first round which we started June 7th and finished June 19th, pH, water temperature, turbidity and conductivity were measured on site. The starting site was the Macarretane dam, the point were the Limpopo River flows in to the main canal. Then the measurements were taken along the irrigation and drainage canals until the points where the drainage canals reach the Limpopo River and the lake was reached. The temperature was always measured straight from the water and at some sites also the pH and the conductivity were measured straight from the canal. For analyzing the turbidity the sample was always collected into a container and the measurements were done immediately.

On the second round which we started June 28th and finished July 2nd, only the most important points were selected and the starting point was on the upper course again. This time all the samples were taken into containers and the analyzing was done later in a house in Chókwé. At the second round the measurements could not be done on site because the reagents were in a form of powder and the weather was very windy. Only the temperature of the water was measured on site.

7.3 Statistical analyses

The measurement data was analyzed using the SPSS software for Windows version 16.0. SPSS is a program which enables a data-management system and statistical analysis in a graphical district. SPSS uses simple dialog boxes and descriptive programme. Most of the tasks can be made by using the mouse only. (SPSS, 2008)

7.3.1 Paired samples T-test

In the statistical testing the paired samples t-test is used because it is the best way to determine whether there is a measurable difference between the mean values of the same measurement made under two different conditions. There are two separate measurements and paired samples T-test is based on the differences between the values. The common hypothesis is that the difference in the mean values is zero. (Rouncefield, M. 1998)

The pairs that were used in this paired samples T-test were selected according the location of the sites on the map. This research is reliable.

8 RESULTS

In this chapter the results of the tests are examined. In the first chapter the statistics of all parameters are reviewed together. The statistics do not include temperature because it is not relevant in the test. Temperature is significant only in the measuring of pH. Table 3 delineates the means and standard deviations of all the parameters individually. In the next chapter the bar charts which delineate the differences between the drainage and irrigation channels in the sampling points can be seen. Finally, the results of the paired sample T-test can be seen. These results are the main source in the analysis of the results.

Table 3. The statistics of all parameters together:

Parameter	Irrigation Mean	Irrigation St.Deviation	Irrigation N	Drainage Mean	Drainage St. Deviation	Drainage N
Conductivity (µS)	482,25	62	16	955,00	522,98	12
pH	8,1	0,95	16	7,62	0,29	12
Turbidity (FAU)	4,67	2,9	16	4,6	3,14	12
Nitrate (NO2-) mg/L	0,003	0,003	13	0,0032	0,0033	11
Dissolved Oxygen (O2) mg/L	7,2	2,04	9	5,9	1,12	5
Phosphorus (PO4) mg/L	0,75	0,64	13	0,86	0,42	9

In the table 3 the average, standard deviation and number of samples from all parameters can be seen. The differences between the irrigation channels and the drainage channels can be compared from the table 3.

8.1 Results of all the irrigation and drainage channels as individual groups

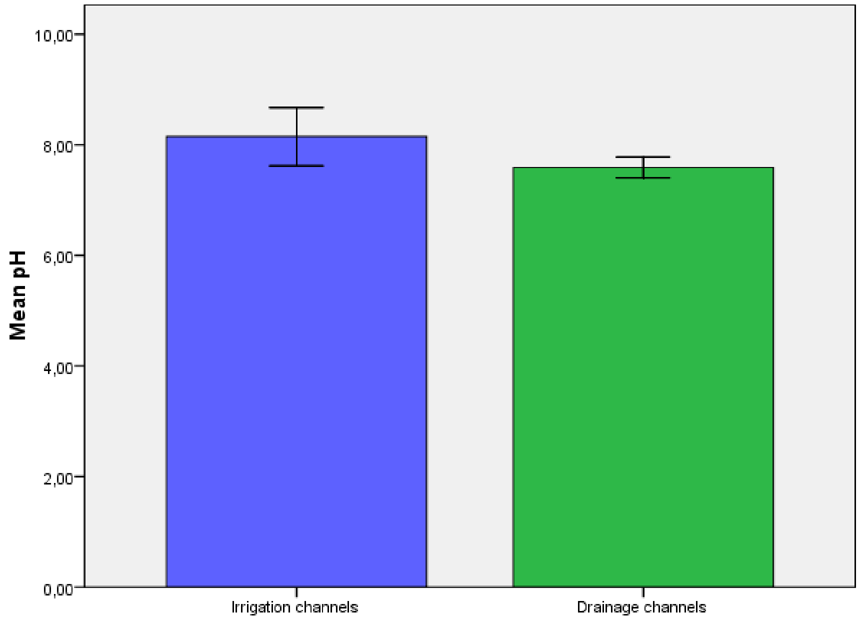


Figure 1. Averages and the error bars of pH-values

Figure 1 delineates the pH-value difference between irrigation channels and drainage channels. In the blue bar chart there are the average and the error bar (95%) of irrigation water. The average of pH in the irrigation channels is 8.1 and the standard deviation is 0,95 (table 3). In the green bar chart there are the average and the error bar (95%) of drainage channels. The average in the drainage channels is 7,62 and the standard deviation is 0,29 (table 3). The figure shows that the pH in the irrigation channels is higher than in the drainage channels but the variations are not remarkable.

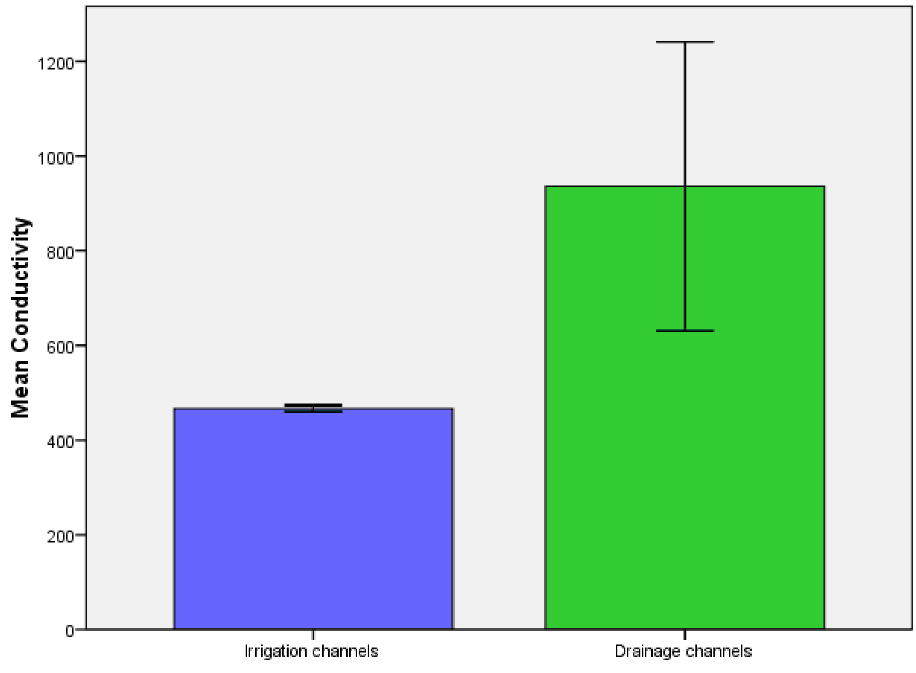


Figure 2. Averages and the error bars of conductivity /µS

Figure 2 delineates the conductivity concentration difference between irrigation channels and drainage channels. In the blue bar chart there are the average and the error bar (95%) from the irrigation channels. The average of the irrigation channels is 482,25µS and the standard deviation is 62 (table 3). In the green bar chart there are the average and the error bar (95%) from drainage channels. The average of the drainage channels is 955µS and the standard deviation is 522,98µS (table3). From the figure 2 it can be seen that the conductivity in the irrigation channels is much lower than in the drainage channels and there is only little variation. In the drainage channels there is lots of variation.

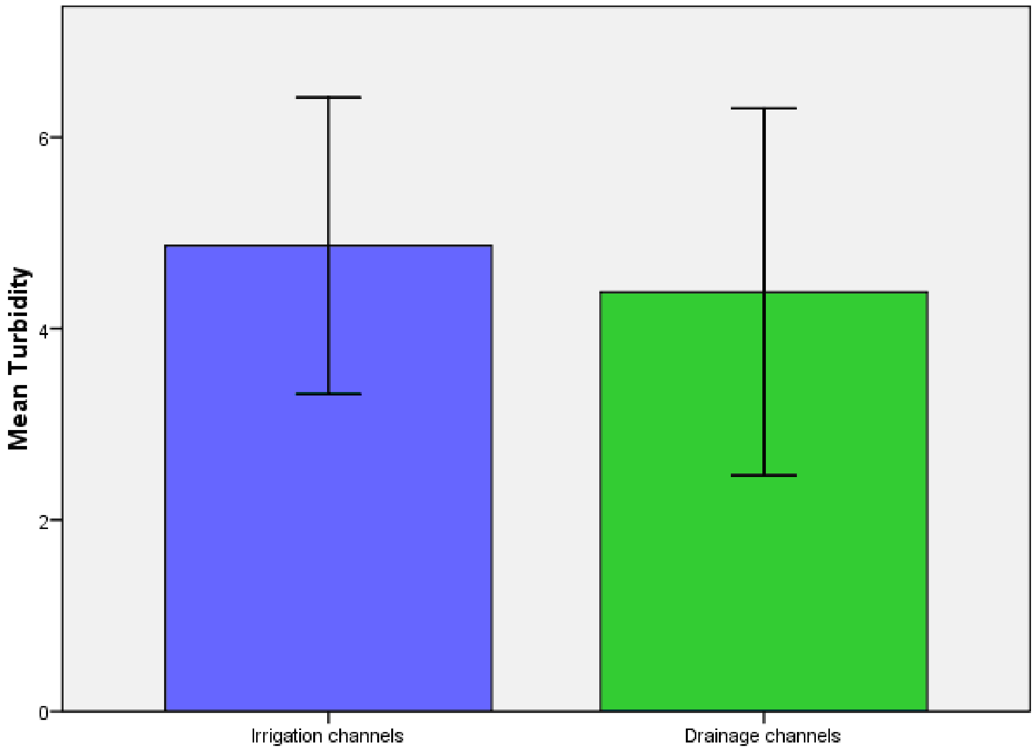


Figure 3. Averages and the error bars of turbidity (FAU)

Figure 3 delineates the turbidity differences between the irrigation- and drainage channels. In the blue bar chart there are the average and the error bar (95%) from the irrigation channel. The average in the irrigation channels is 4,6 and the standard deviation is 2,9 (table 3). In the green bar chart there are the average and the error bar (95%) of drainage channels. The average in the drainage channels is 4,67 and the standard deviation is 3,7 (table 3). The differences between the irrigation- and drainage channels are not remarkable because the averages are similar and there is a lot of variation in both irrigation- and drainage channels.

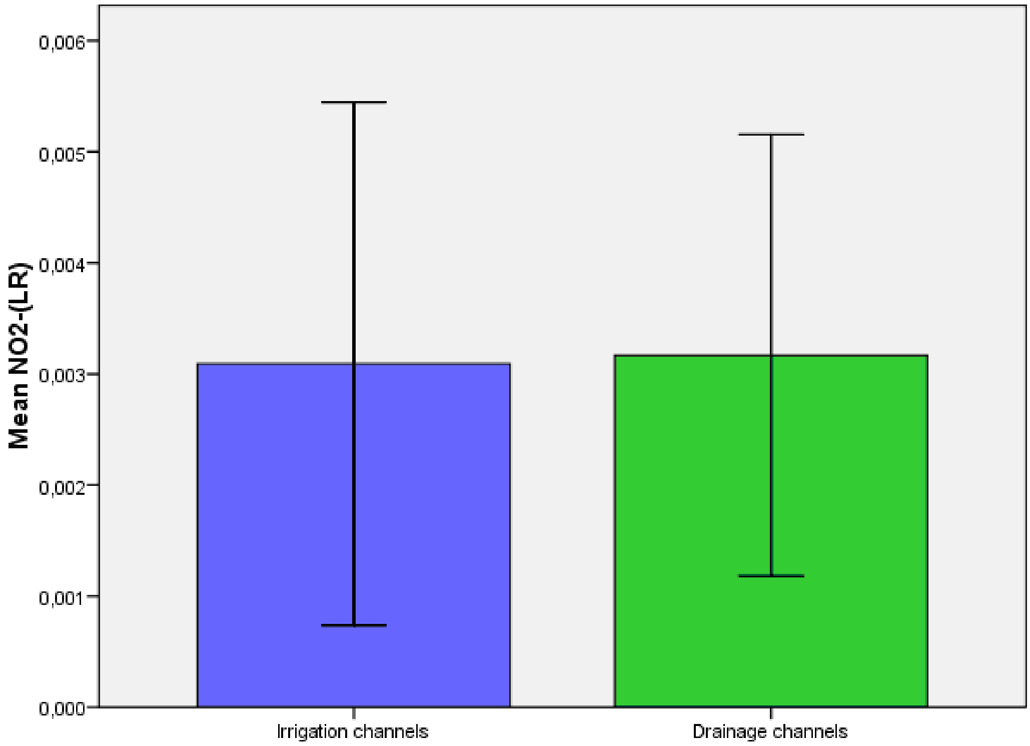


Figure 4. Averages and the error bars of nitrate mg/L

Figure 4 delineates the nitrate differences between the irrigation- and drainage channels. In the blue bar chart there are the average and the error bar (95%) from the irrigation channels. The average of the irrigation channels is 0,003 and the standard deviation is also 0,003 (table 3). In the green bar chart there are the average and the error bar (95%) of drainage channels. The average of drainage channels is 0,0032 and the standard deviation is 0,0033 (table 3). The differences between the irrigation and the drainage channels are not remarkable because the averages are very similar and there is lots of variation in both irrigation- and drainage channels. The nitrate concentration is also under the Mozambican standards of quality of water (table 2).

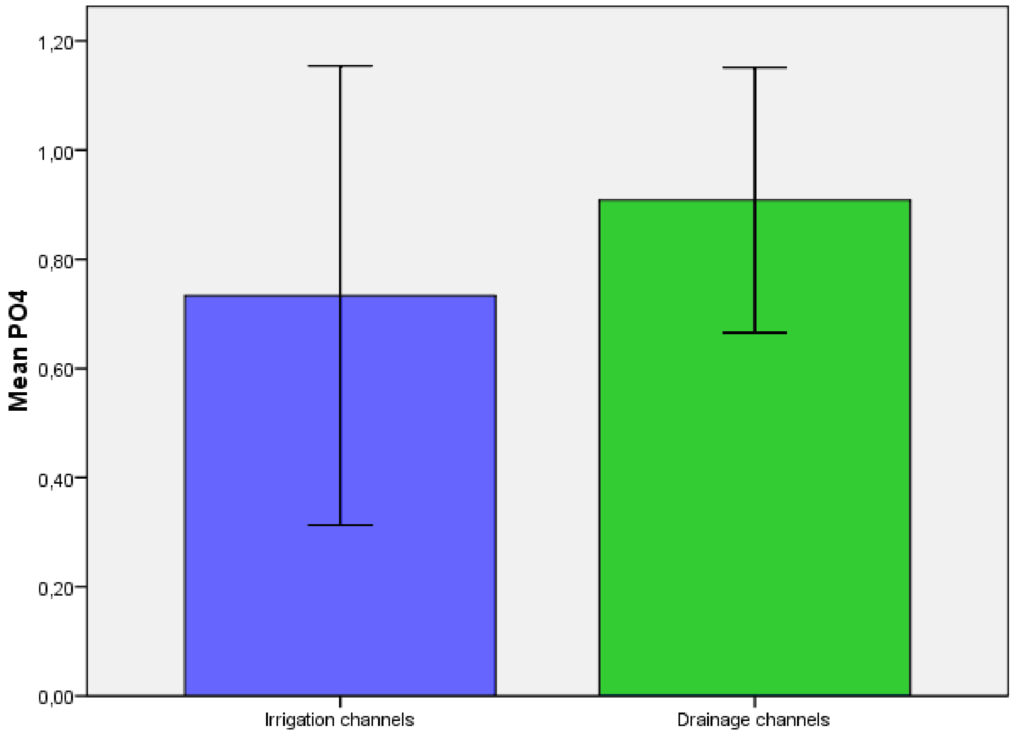


Figure 5. Averages and error bars of phosphorus mg/L

Figure 5 delineates the phosphorus concentration differences between the irrigation- and drainage channels. In the blue bar chart there are the average and the error bar (95%) from irrigation channels. The average in the irrigation channels is 0,75 and standard deviation is 0,64 (table 3). In the green bar chart are the average and the error bar (95%) from drainage channels. The average in the drainage channels is 0,86 and standard deviation is 0,42 (table 3). The differences between the irrigation and the drainage channels are not remarkable because the averages are very similar and there is lots of variation in both irrigation- and drainage channels. The phosphorus concentration is also under the Mozambican standards of quality of water (table 2).

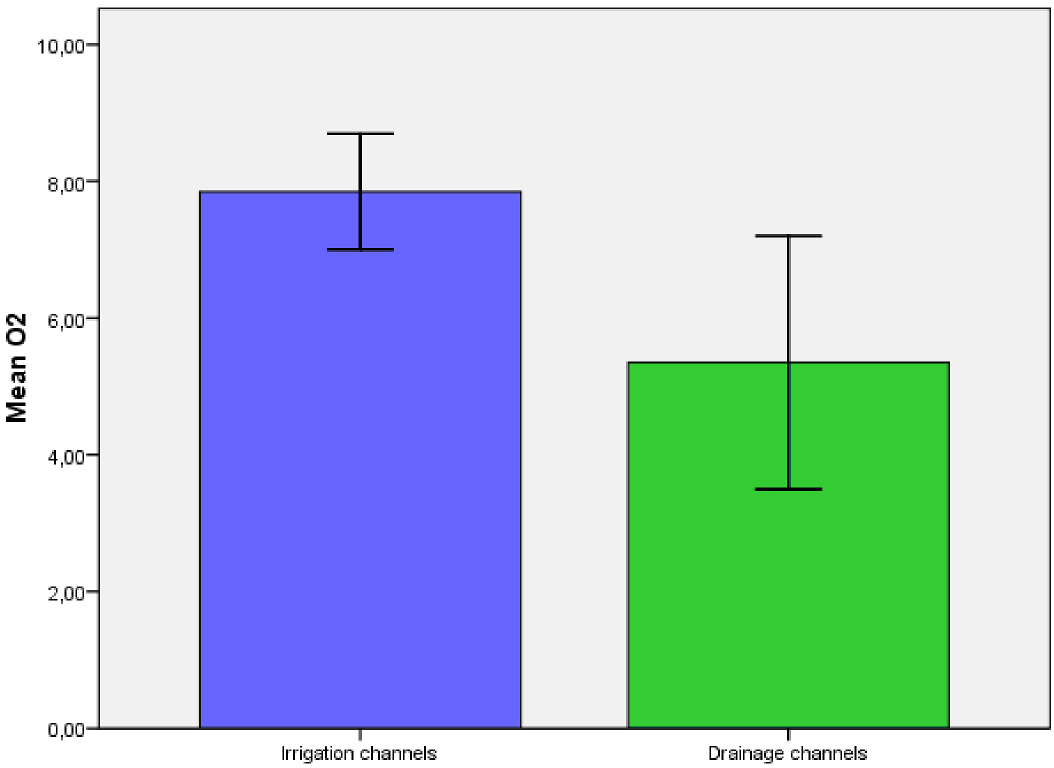


Figure 6. Averages and the error bars of dissolved oxygen mg/L

Figure 6 delineates the dissolved oxygen concentration differences between irrigation- and drainage channels. In the blue bar chart there are the average and the error bar (95%) of irrigation channels. The average in the irrigation channels is 7,2 and the standard deviation is 2,04 (table 3). In the green bar chart there are the average and the error bar (95%) of drainage channels. The average in the drainage channels is 5,9 and the standard deviation is 1,12 (table 3). In the drainage channels the dissolved oxygen concentration is under the Mozambican standards of quality of water (table 2).

8.2 Differences between irrigation water and drainage water -Paired measurements

8.2.1 Conductivity differences between irrigation water and drainage water

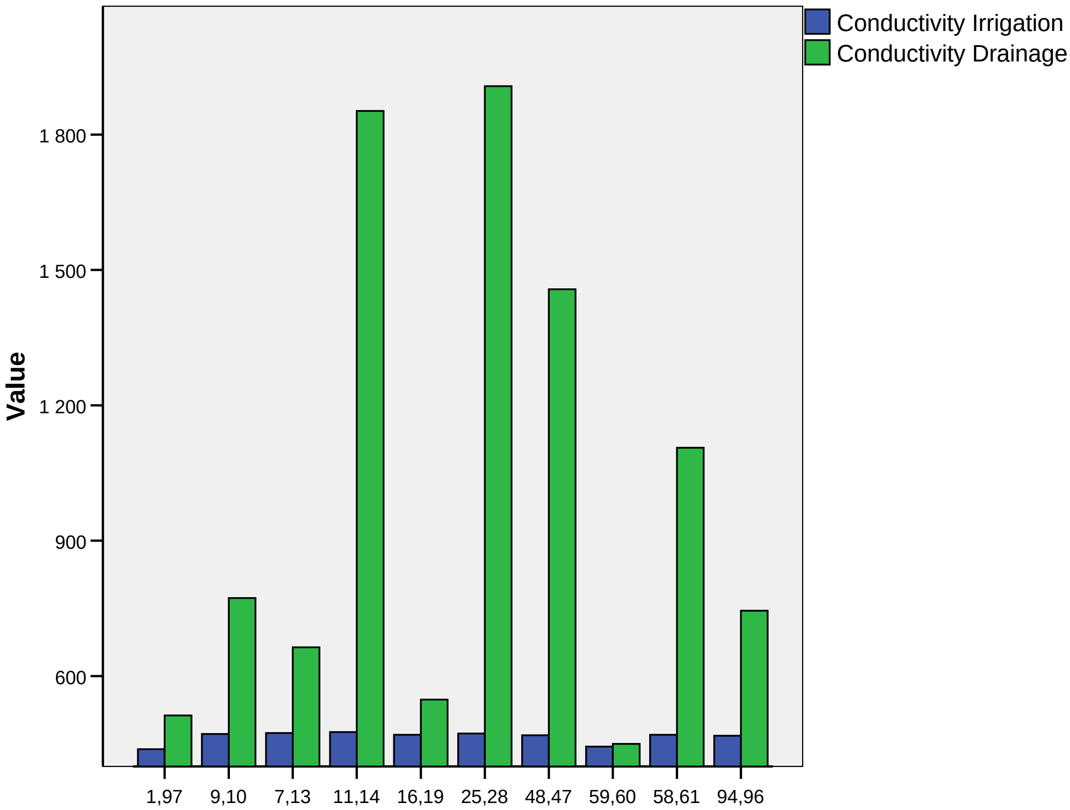


Figure 7. Conductivity values (µS) of 10 irrigation- and drainage channels

What can be seen from the figure 7 is that the conductivity is higher in the drainage channels than in the irrigation channels. Station 1 was taken from the upstream just behind the Macarretane dam where the water flows to the irrigation and drainage system. Station 97 was taken from the drainage channel in downstream where the water flows from the irrigation system back to the Limpopo River. In the middle of the irrigation and drainage system most of the conductivity values get notably higher in the drainage channels. In the station 11 (irrigation channel) the conductivity is 448 µS. After the irrigation the conductivity value has got notably higher. The conductivity in the station 14 (drainage channel) is 1406 µS. The same remarkable differences between the irrigation- and the drainage channels can also be seen in the stations 25 and 28, 48 and 47and also 58 and 61. In the station 48 (irrigation channel) the conductivity value is 469 µS. After the irrigation the conductivity value has got higher up to 1457 µS in the station 47 (drainage channel). Stations 25 and 28 show that after the irrigation the conductivity has got higher. Conductivity in the irrigation water in the station 25 is only 473 µS. After the irrigation the water conductivity has increased from 473 µS to 1907 µS.

8.2.2 pH differences between irrigation water and drainage water

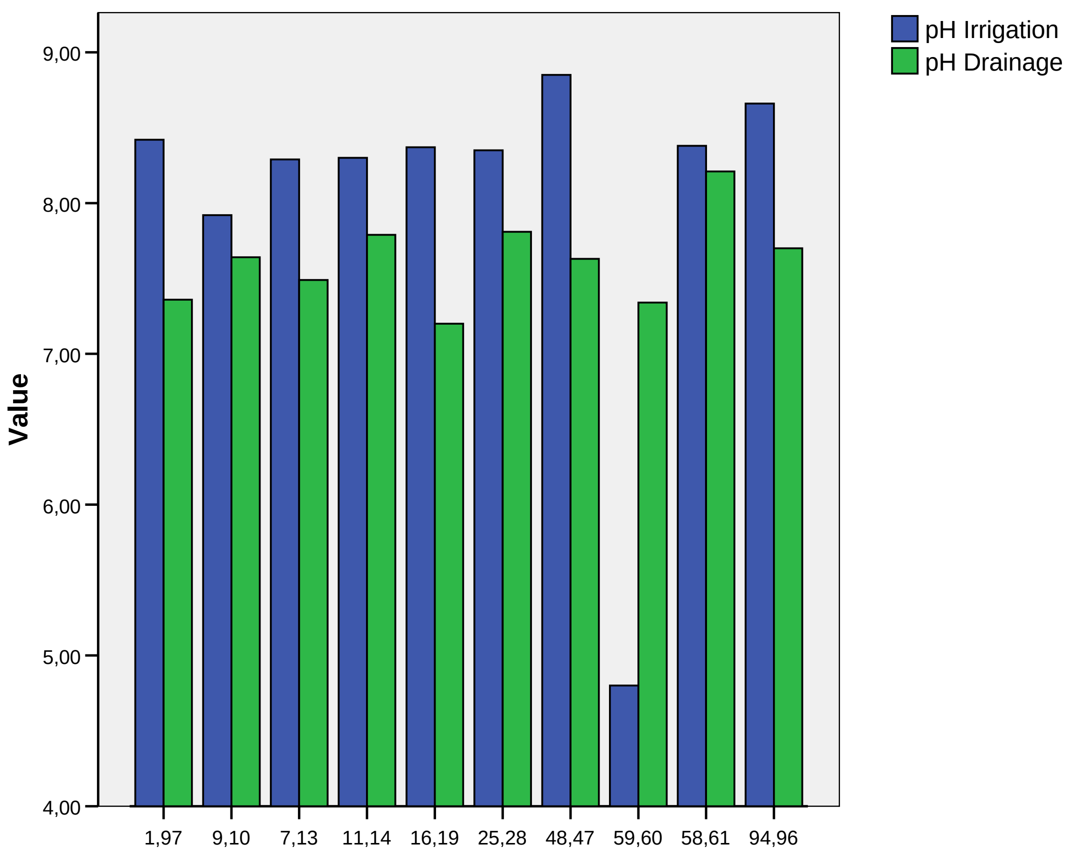


Figure 8. pH values of 10 irrigation- and drainage channels

Figure 8 delineates pH differences between the water of irrigation channels and the water of drainage channels. It shows that pH values are higher in the irrigation channels than drainage channels. Differences between the irrigation- and drainage channels are not very high. In the figure 8 station 1 was taken from the upstream little north from the Macarretane dam where the water flows to the irrigation- and drainage system. The water flows to the station 1 straight from the Limpopo River. The pH-value in the station 1 was 8,2. From the downstream station 97 the irrigated water goes back to the Limpopo River. There the pH-value was 7,36. In one of the cases the pH-value is higher in the drainage channel. In station 59 in the irrigation channel the pH is 4,83. After the irrigation of fields drainage waters pH-value in the station 60 is 7,34. In this case the soil may have been alkaline, which causes a raise in pH-values in the irrigated water.

8.2.3 Nitrate concentration differences between irrigation and drainage water

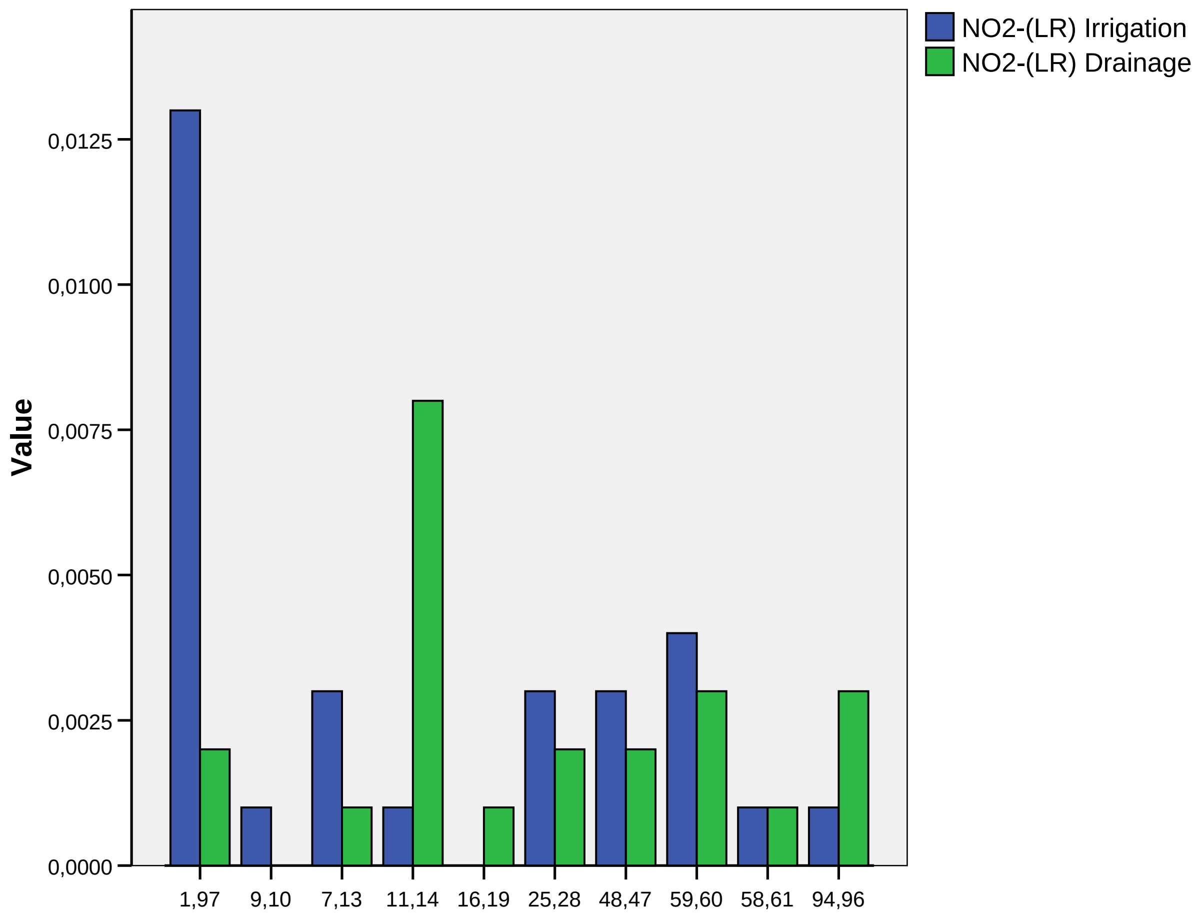


Figure 9. Nitrate values (mg/L) of 9 irrigation- and drainage channels.

Figure 9 delineates that in the irrigation system there is a lot of variety in nitrate concentration. The nitrate values are really low compared to

Mozambican standards (table 2). Upstream station 1, which is little to the north from the Macarretane dam, the nitrate concentration is very high 0,013 mg/L. It is the as nitrate concentration of the Limpopo River water. In the station 97, which is located in the downstream where the irrigated water goes back to the river, the nitrate concentration is only 0,002 mg/L. The figure 9 shows that in the most of the cases nitrate concentration is higher in the irrigation channels than in the drainage channels. In some of the cases the nitrate concentration is lower in the irrigation channels than in the drainage channels. Differences between the irrigation and drainage channels are not big.

8.2.4 Phosphorus concentration differences between irrigation water and drainage water

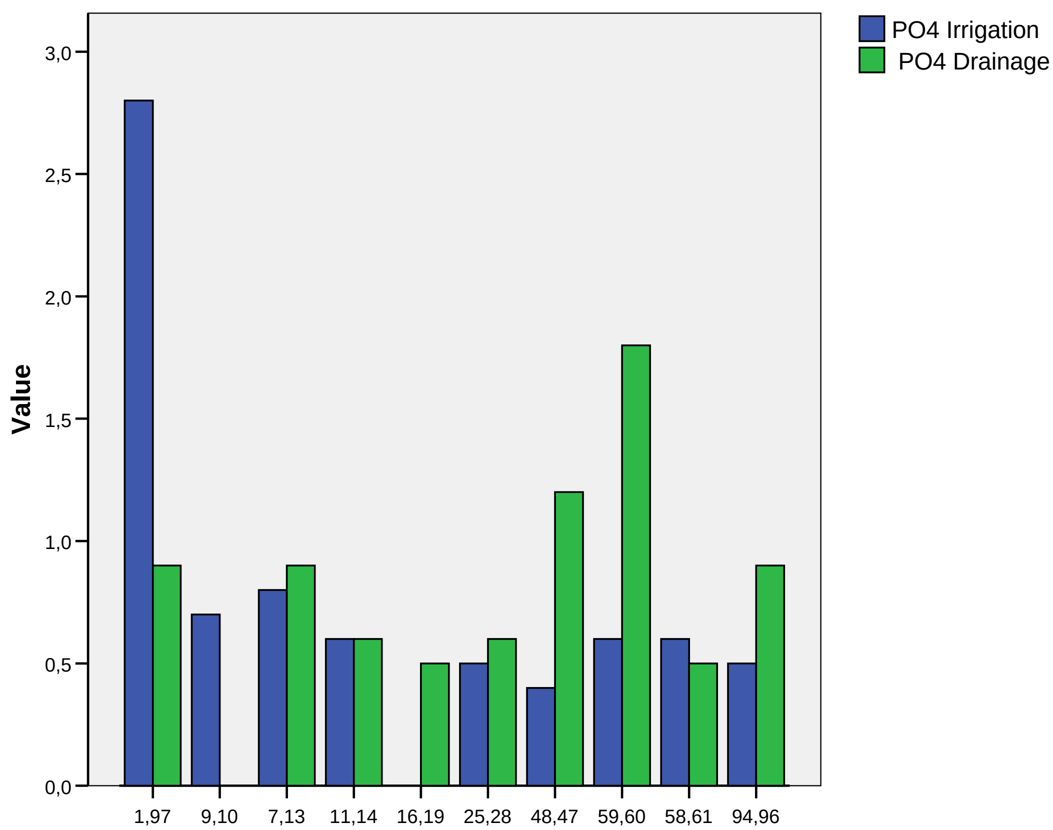


Figure 10. Phosphorus values (mg/L) of 9 irrigation- and drainage channels

Figure 10 shows that the irrigation system has lots of variety in phosphorus concentration. The main remarkable differences are between stations 1 and

97. In the upstream station 1 where the water flows to the irrigation system the phosphorus concentration is very high. In the downstream station 97 the phosphorus concentration is much lower than in the upstream. In most of the cases the phosphorus concentration got higher after the irrigation. Only in few cases the phosphorus concentration got lower in the irrigated water. In two cases the phosphorus concentration was not measured (station 10 and station 16).

8.2.5 Turbidity value differences between irrigation water and drainage water

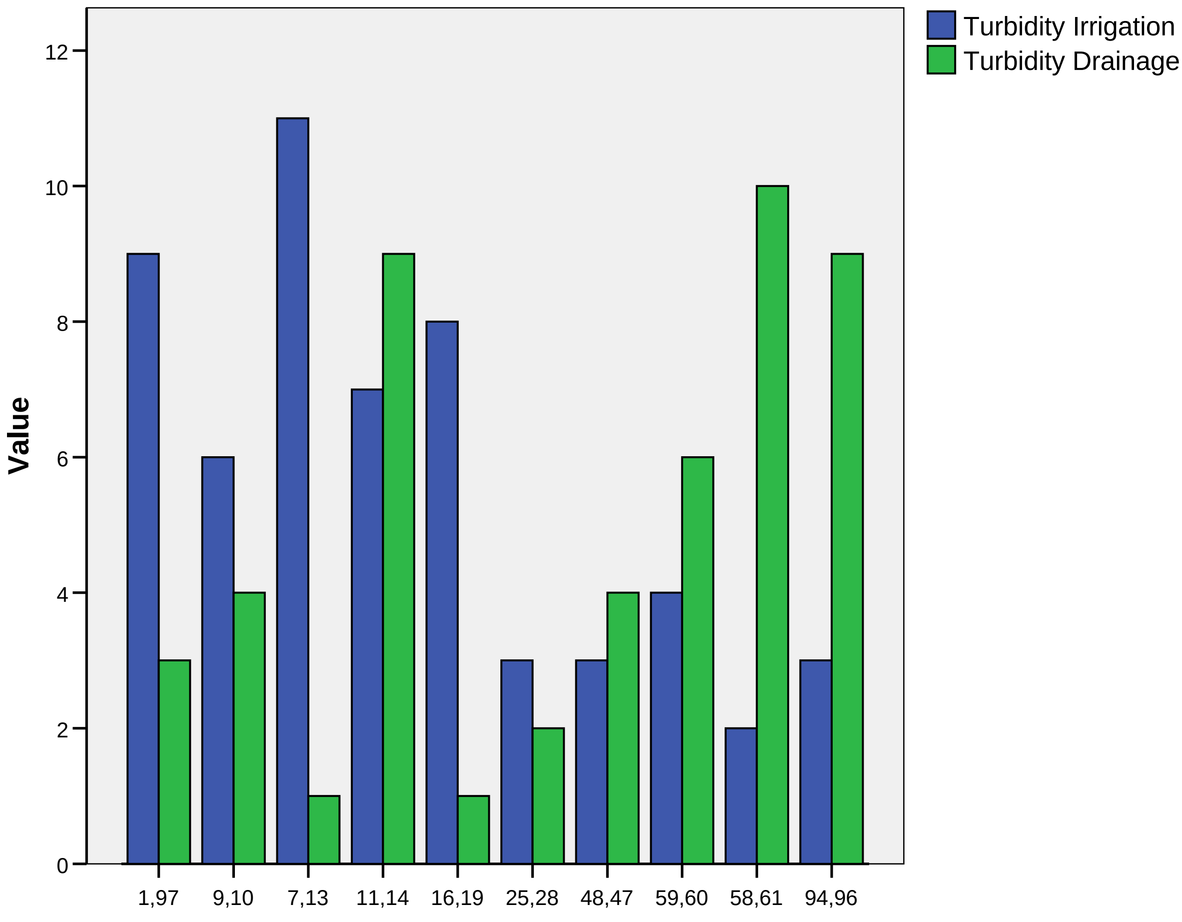


Figure 11. Turbidity values (FAU) of 10 irrigation- and drainage channels.

Figure 11 shows that there is lot of variety of turbidity. In a half of the 10 cases the turbidity value is lower in the irrigation channels and in a half of the cases the turbidity value is higher in the drainage channels. In the upstream station 1 where the water flows to the irrigation system the turbidity value is high (9 FAU). In the downstream station 97 the turbidity value is much lower (3 FAU) than in the upstream.

8.3 Results of the paired samples T-test

In the statistical testing we use 40 sampling points which are 20 sampling points from the irrigation channels and 20 sampling points from the drainage channels. The sampling points are selected so that the sampling points of channels are connected together.

In this research the statistical testing significance level is 0, 05.

Hypothesis: The irrigation system has an impact on the conductivity of the water.

Table 4. The test statistics of conductivity.

Subject	Mean	Std. deviation	N	Sig. (2-tailed)
1 Conductivity	503,70	147,549	20	0,017
2 D_conductivity	766,15	424,594	20	

Conclusions: The hypothesis is correct. The test Statistic (0,017) is below the significance level (0, 05). Conductivity (1) is measured from the irrigation channels. 503, 70 is the average value of conductivity measured from the irrigation channels from 20 stations and 147,549 is the standard deviation of conductivity measured from the same stations. D_conductivity (2) is measured from the drainage channels. 766, 15 is the average value of conductivity measured from the drainage channels from 20 stations and 424,594 is the standard deviation of conductivity measured from the same stations.

Hypothesis: The irrigation system has an impact on the pH- value of the water.

Table 5. The test statistics of pH.

Subject	Mean	Std. deviation	N	Sig. (2-tailed)
1 pH	8,2456	0,29147	18	0,001
2 D_pH	7,8300	0,43419	18	

Conclusions: The hypothesis is correct. The test Statistic (0,001) is below significance level (0, 05). pH (1) is measured from the irrigation channels. 8, 2456 is the average value of pH measured from the irrigation channels from 18 stations and 0, 29147 is the standard deviation of pH measured from the same stations. D_pH (2) is measured from the drainage channels. 7, 8300 is the average value of pH measured from the drainage channels from 18 stations and 0, 43419 is the standard deviation of pH measured from the same stations.

Hypothesis: The irrigation system has an impact on the turbidity of the water.

Table 6. The test statistics of turbidity.

Subject	Mean	Std. deviation	N	Sig. (2-tailed)
1 Turbidity	4,35	3,360	20	0,976
2 D_turbidity	4,30	6,689	20	

Conclusions: The hypothesis is not correct. The test Statistic (0,976) is over the significance level (0, 05). Turbidity (1) is measured from the irrigation channels. 4, 35 is the average value of turbidity measured from the irrigation channels from 20 stations and 3,360 is the standard deviation of Turbidity measured from the same stations. D_turbidity (2) is measured from the drainage channels. 4, 30 is the average value of turbidity measured from the drainage channels from 20 stations and 6,689 is the standard deviation of turbidity measured from the same stations.

Hypothesis: The irrigation system has an impact on the nitrate concentration of the water.

Table 7. The test statistics of Nitrate.

Subject	Mean	Std. deviation	N	Sig. (2-tailed)
1 Nitrate	0.00275	0.002252	8	0,636
2 D_nitrate	0,00363	0,003962	8	

Conclusions: The hypothesis is not correct. The test Statistic (0,636) is over significance level (0,05). Nitrate (1) is measured from the irrigation channels. 0,00275 is the average value of nitrate measured from the irrigation channels from 8 stations and 0,002252 is the standard deviation of nitrate measured from the same stations. D_nitrate (2) is measured from the drainage channels. 0,00365 is the average value of nitrate measured from the drainage channels from 8 stations and 0,003962 is the standard deviation of nitrate measured from the same stations.

Hypothesis: The irrigation system has an impact on the phosphorus concentration of the water.

Table 8. The test statistics of phosphorus.

Subject	Mean	Std. deviation	N	Sig. (2-tailed)
1 Phosphorus	0,850	0,7964	8	0,787
2 D_phosphorus	0,938	0,4207	8	

Conclusions: The hypothesis is not correct. The test Statistic (0,787) is over the significance level (0,05). Phosphorus (1) is measured from the irrigation channels. 0,850 is the average value of phosphorus measured from the irrigation channels from 8 stations and 0,7964 is the standard deviation of phosphorus measured from the same stations. D_ phosphorus (2) is measured from the drainage channels. 0,938 is the average value of phosphorus measured from the drainage channels from 8 stations and

0,4207 is the standard deviation of phosphorus measured from the same stations.

9 CONCLUSIONS AND DISCUSSION

The main objective of this study was to research the impact of the irrigation system and agricultural production on water quality in an irrigation system. The irrigation system which was studied is situated in Chókwé, Mozambique. The aim was to determine the impacts of the irrigation system on the environment of the area and the source of the problem as well as possible mitigation measures.

The parameters investigated were; nitrate concentration (NO_{3-}), phosphorus concentration (PO_4), pH-value, conductivity (µS), turbidity (FAU) and dissolved oxygen (DO).

Results of this study show that the pH-value decreases when the water goes through the irrigation and drainage system. The difference is not big but consistent and statistically significant. Figure 1 (p. 46.) shows the pH-values of all the irrigation and drainage channels as individual groups. In the figure 1 the difference between the results from the irrigation and the drainage channels is not very significant. Also the standard deviation is not substantial. Figure 8 (p. 53.) demonstrates the differences between water of irrigation channels and water of drainage channels as ten different pairs. In the figure 8 the decrease of the pH-value is more obvious. Table 5 (p. 58.) shows the results of the paired samples T-test. The hypothesis was that the irrigation system has an impact to the pH-value of the water. The test statistics 0,001 stayed under the significance level 0,05. In conclusion, the irrigation system has a statistically significant impact on the pH-value of the water in the irrigation scheme. Although the irrigation system has an impact on the quality of the water, the pH- value is quite high to begin with; the actual impact is not very alarming. In the long run, because the farmers use irrigated water again, the reuse of irrigated water may cause soil acidification. It might also affect the water quality in the Limpopo River because of the decreasing of the pH-value.

The results of the conductivity- measurements show that the conductivity increases as the water goes through the irrigation system. Figure 2 (p. 47.) shows the conductivity of all the irrigation and the drainage channels as individual groups. In the figure 2 the difference between the results from the irrigation and the drainage channels is significant; the conductivity increases almost by half. The standard deviation varies a lot in the drainage channels. On the other hand, there is only little variation in the irrigation channels. Figure 7 (p. 52.) demonstrates the differences between the water of the irrigation channels and water of the drainage channels as ten different pairs. Figure 7 shows that the increasing of the conductivity is very distinct. Table 4 (p. 57.) shows the results of the paired samples T-test. The hypothesis was that the irrigation system has an impact to the conductivity of the water. Test statistics 0,017 stayed under the significance level 0,05. In conclusion, the irrigation system has a statistically significant impact on the conductivity concentration of the water in the irrigation scheme. High conductivity levels can stem from salinity in the soil. Some fields in the area are so salty, that cultivation and crop production are impossible. The reuse of the irrigated water may also have an impact on the salinity levels of the water, because the salt and other compounds accumulate in the water. The use of saline water in the irrigation might cause the fields to become uncultivable.

The results of the turbidity measures show that the turbidity decreases slightly as the water goes through the irrigation system. Figure 3 (p. 48.) shows the turbidity of all the irrigation and drainage channels as individual groups. In the figure 3 the difference between the results from the irrigation and drainage channels are not significant. There is a lot of variation both in the drainage and irrigation channels. Figure 11 (p. 56.) demonstrates the differences between the water of irrigation channels and the water of drainage channels as ten different pairs. In the figure 11 no conclusive results can be seen. The variations in the figure 11 are not consistent. Table 6 (p. 58.) shows the results of the paired samples T-test. The hypothesis was that the irrigation system has an impact on the turbidity of the water. The test statistics 0,976 is over the significance level 0,05. In conclusion, the irrigation system has no statistically significant impact on the turbidity of the water in the irrigation scheme. Turbidity of the water is affected by many different things like velocity of water, rainfall, amount of water plants and what kind of channel is in question. If the channel is in direct contact with the soil, the turbidity is usually higher. If there is lots of vegetation the plants have a cleaning effect, the water is clear and the turbidity often very low.

The results of the nitrate measures show that the nitrate level increases very slightly as the water goes through the irrigation system. Figure 4 (p. 49.) shows the nitrate levels of all the irrigation and drainage channels as individual groups. In the figure 4 the difference between the results from the irrigation and drainage channels are not significant. There is a lot of variation both in the drainage and the irrigation channels. Figure 9 (p. 54.) demonstrates the differences between water of the irrigation channels and water of the drainage channels as ten different pairs. In the figure 9 no conclusive results can be seen. The variations in the figure 9 are not consistent. Table 7 (p. 59.) shows the results of the paired samples T-test. The hypothesis was that the irrigation system has an impact on the nitrate concentration of the water. The test statistics 0,636 is over the significance level 0,05. In conclusion, the irrigation system has no statistically significant impact on the nitrate concentration of the water in the irrigation scheme. The nitrate levels occur in such a low range, that they do not have any impact on the water or the environment at this moment. The nitrate levels in the water are well under the recommendation values.

The results of the phosphorus measures show that the phosphorus level increases slightly as the water goes through the irrigation system. Figure 5 (p. 50.) shows the phosphorus levels of all the irrigation and the drainage channels as individual groups. In the figure 5 the difference between the results from the irrigation and the drainage channels are not significant. There is a lot variation both in the drainage and irrigation channels. Figure

10 demonstrates the differences between the water of the irrigation channels and the water of the drainage channels as ten different pairs. In the figure 10 (p. 55.) no conclusive results can be seen. The variations in the figure 10 are not consistent. Table 8 (p. 59.) shows the results of the paired samples T-test. The hypothesis was that the irrigation system has an impact to the phosphorus of the water. Test statistics 0,787 is over the significance level 0,05. In conclusion, the irrigation system has no statistically significant impact on the phosphorus concentration of the water in the irrigation scheme. Phosphorus levels occur in such a low range, that they do not have any impact to the water or the environment. Phosphorus levels in the water are well under the recommendation values.

The results of the dissolved oxygen measures show that the oxygen level decreases slightly as the water goes through the irrigation system. Figure 6 (p. 51.) shows the dissolved oxygen levels of all the irrigation and drainage channels as individual groups. In the figure 6 the difference between the results from the irrigation and drainage channels are not significant. There is a lot of variation in the drainage channels and some in the irrigation channels. In the results of the dissolved oxygen there are no figures which demonstrate the differences between the water of the irrigation channels and the water of the drainage channels as ten different pairs or the paired samples T-test. The sampling of the dissolved oxygen was incomplete because of the lack of reagents. There should be more studies about the dissolved oxygen in the future.

It should be taken in to consideration that the water samples were taken during the dry winter season. The results would probably be different, if the samples were taken in the rainy season during summer when there is more nutritional leakage from the fields and more water in the irrigation and drainage channels. Also the results regarding the turbidity would probably be different because of the increased movement of the water. In summertime the sites are impossible to reach, but it would be interesting to see how the results would change during the rainy season. One problem which was faced in taking the samples was the condition of the roads. All the sites were too far to walk to and some places were impossible to get to even by an all-terrain vehicle. There was also a problem of getting the reagents that were needed to determine the nutrient levels of the water. It was not possible to bring the reagents from Finland, like it was done with the other equipment, because the reagents are classified as poison and it is not possible to transport them on a passenger plane. The reagents were ordered from South Africa.

In the future studies regarding water quality extra attention should be focused on a more functional research frame. Examined pairs should be selected carefully and included in the research plan. The fieldwork is easier when the pairs are previously selected and the sample points sought out beforehand. A recently updated map, including all possible roads of the area is essential to the fluency of the fieldwork. If the future water analyses are done using reagents, they should be ordered beforehand from the reagents distribution centre in South Africa. A lot of time must be reserved in getting the reagents. Also all the other equipment should be arranged to the site as early as possible.

In conclusion, the irrigation system and the agricultural production in the area have a statistically significant impact on the quality of water in the Chókwé irrigation scheme. According to this research, the most significant differences occur in the pH-values and in the conductivity levels. The water quality is generally satisfactory, but since the water demand is probably going to increase, more pressure will be put on this diminishing resource. Because the water in the Limpopo River and in the channels is in heavy use, more specific studies in the future are needed. In addition to more water studies, there could be studies about the vegetation or the occurrence of different kind of organisms. Also a research about the condition of the soil, which could include a soil enrichment plan, is prospective in the future.

10 SOURCES

Central Intelligence Agency (CIA). 2008. The World Factbook. Washington D.C. US. Retrieved February 20, 2008, from https://www.cia.gov/library/publications/the-world-factbook/geos/mz.html

Chilundo, M.N.C. *Design of a Water Quality Monitoring Network for the Limpopo River Basin in Mozambique.* 2007. Netherlands: UNESCO-IHE Institute for Water Education.

Connell, D.W. 2005. *Basic Concepts of Environmental Chemistry*. 2th ed. Boca Raton, FL: Taylor & Francis Group

D. K, Majumdar. 2004. Irrigation Water Management: Principles and Practice. New Delhi, India: Prentice-Hall of India Private Limited.

Kroemer, H. Kittel, 1980. C. *Thermal Physics*. 2th ed. W.H. Freeman Company.

Lake Superior-Duluth Streams. 2008. Environmental Monitoring for Public Access and Community Tracking (EMPACT), Minnesota's Lake Superior Coastal Program, National Oceanic and Atmospheric Administration. Retrieved March 20, 2008 from http://www.duluthstreams.org/index.html

Louw, A. Gichuki, F. 2003. *Limpopo basin profile: Strategic research for enhancing agricultural water productivity (draft version)*. Challenge Program on Water and Food.

Manahan, S.E. 2000. *Environmental Chemistry.* 7th ed. Boca Raton, FL: Lewis Publishers.

National Science Foundation. 2007. Water on the Web (WOW) - Monitoring Minnesota Lakes on the Internet and Training Water Science Technicians for the Future - A National On-line Curriculum using Advanced Technologies and Real-Time Data. University of Minnesota-Duluth. Retrieved February 3, 2008, from http://waterontheweb.org/index.html

Oulun Yliopisto, prosessi- ja ympäristötekniikan osasto, systeemitekniikan laboratorio. 2007. 470440A Systeemitekniikan laboratoriotyöt, harjoitustyö n:o 6, johtokyvyn mittaus ja säätö. Oulun yliopisto. Retrieved March 20, 2008 from http://cc.oulu.fi/~posyswww/opiskelu/sytelabrat/tyo6.pdf

Pereira, L.S. 1999. Higher performance through combined improvements in irrigation methods and scheduling: a discussion. Department of Agricultural Engineering, Istituto Superior de Agronomia, Universidade Técnica de Lisboa, Tapada de Ajuda, Lisboa, Portugal. Retrieved January 17, 2008, from http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T3X-3W9KW23-2&_user=1638579&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000054051&_version=1&_urlVersion=0&_userid=1638579&md5=6808b1f99f8a5025da58649aa1a42ccc

Rouncefield, M. 1998. SPSS into school projects. John Moores University, Liverpool. Retrieved March 4, 2008, from http://www.cms.livjm.ac.uk/spss/paired.htm

Siebert, S. Döll, P. Feick, S. Hoogeveen, J. Faurés, J.-M. Frenken, K. 2000. The Global Map of Irrigation Areas. Insitute of Physical Geography, Germany. University of Frankfurt am Main, Germany. Land and Water Development Division, Food and Agriculture Organization of the United Nations, Rome, Italy. Retrieved March 14, 2008, from http://www.geo.uni-frankfurt.de/ipg/ag/dl/f_poster/poster_gmia_v4_lowres.pdf

Southern African Research and Documentation Centre(SARDC), Musokotwane Environment Resource Centre for Southern Africa (IMERCSA), ZERO - Regional Environment Organization. 2007. The Limpopo River Basin Factsheets. Rapid Environmental Appraisal of the Limpopo River Basin, SADC Water Sector. Retrieved September 5, 2007, from http://www.sardc.net/imercsa/Limpopo/index.htm

The United States Agency for International Agency(USAID)/Famine Early Warning System Network(FEWS NET)/Mozambique Integrated Information Network for Decision-Making(MIND),the Department of Geography at the University of Eduardo Mondlane, the National Institute of Disaster Management (Instituto nacional de gestao de calamidades INGC). 2003. Atlas for preparedness and response in the Limpopo Basin. Cape town, South Africa: Greda Communications (Pty) Ltd.

Tyystjärvi-Muuronen, K. 1985. *Vesiopas-vedet ja vesiluonto*. Mänttä: Mäntän kirjapaino Oy

Universidade Eduardo Mondlane. 2007. Retrieved January 17, 2008, from http://www.uem.mz/

Vuori, K-M. Bäck, S. Helssten, S. Karjalainen, S.M. Kauppila, P. Lax, H-G. Lepistö, L. Londesborough, S. Mitikka, S. Niemelä, P. Niemi, J. Perus, J. Pietiläinen, O-P. Pilke, A. Riihimäki, J. Rissanen, J. Tammi, J. Tolonen, K. Vehanen, T. Vuoristo, H. Westberg, V. 2006. *Suomen pintavesien tyypittelyn ja ekologisen luokittelujärjestelmän perusteet*. Helsinki: Suomen ympäristökeskus

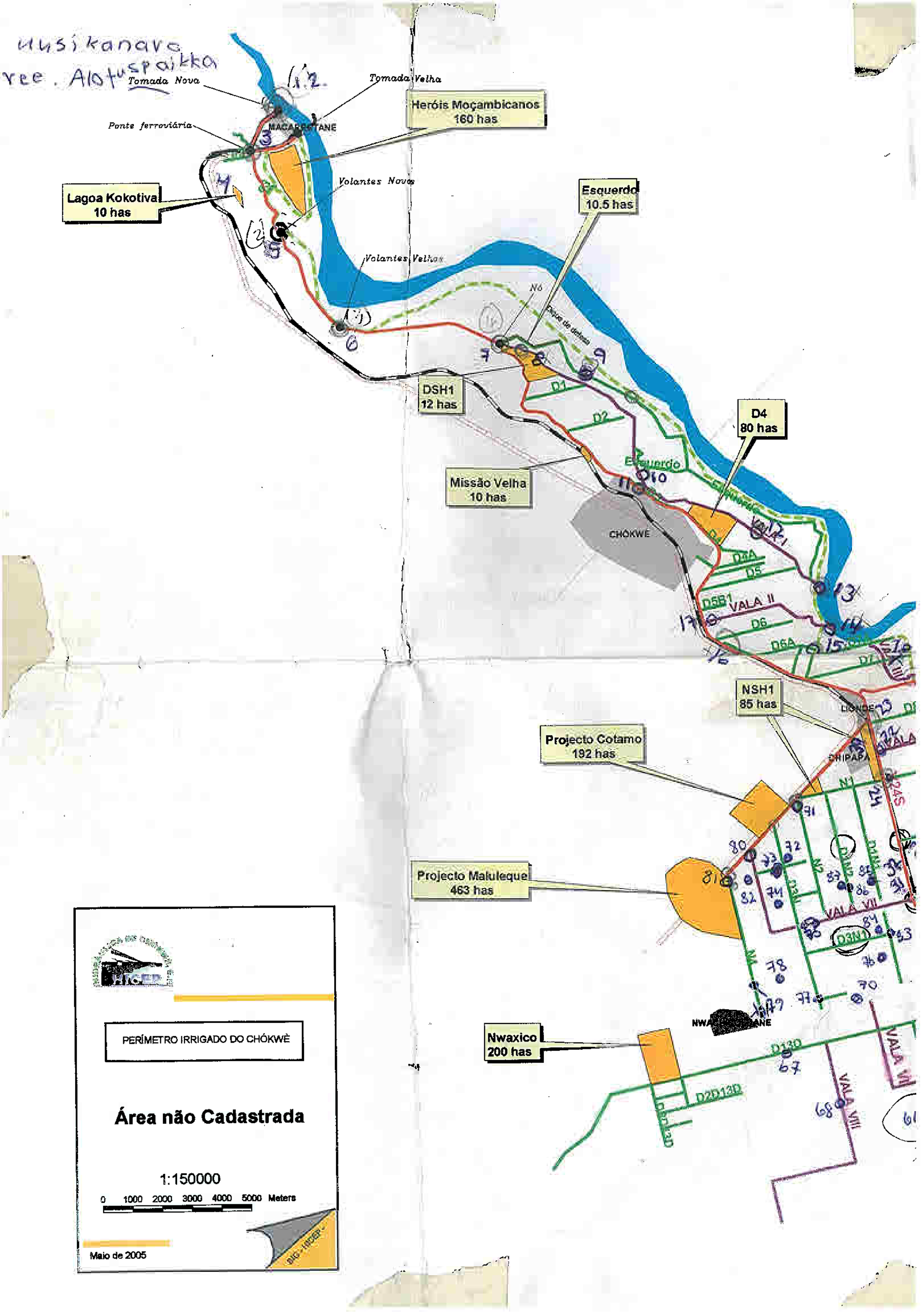
Wikipedia-The Free Encyclopedia. 2007. Retrieved February 5, 2008 from http://en.wikipedia.org/wiki/PH

SUPPLEMENTS

Supplement 1 Map of irrigation system in Chókwé

Supplement 2 Research results

Supplement 3 Research diary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Lagoa Kokotiva
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Esquerdo
10.5 has
Volantes Velhos
Nó
Dique de defesa
DSH1
12 has
D1
D2
D4
80 has
Missão Velha
10 has
Esquerdo
CHÓKWÈ
D4A
D5
D5B1
VALA II
D6
D6A
D7
NSH1
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LIONDE
CHIPAPA
Projecto Cotamo
192 has
N1
Projecto Maluleque
463 has
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D13D
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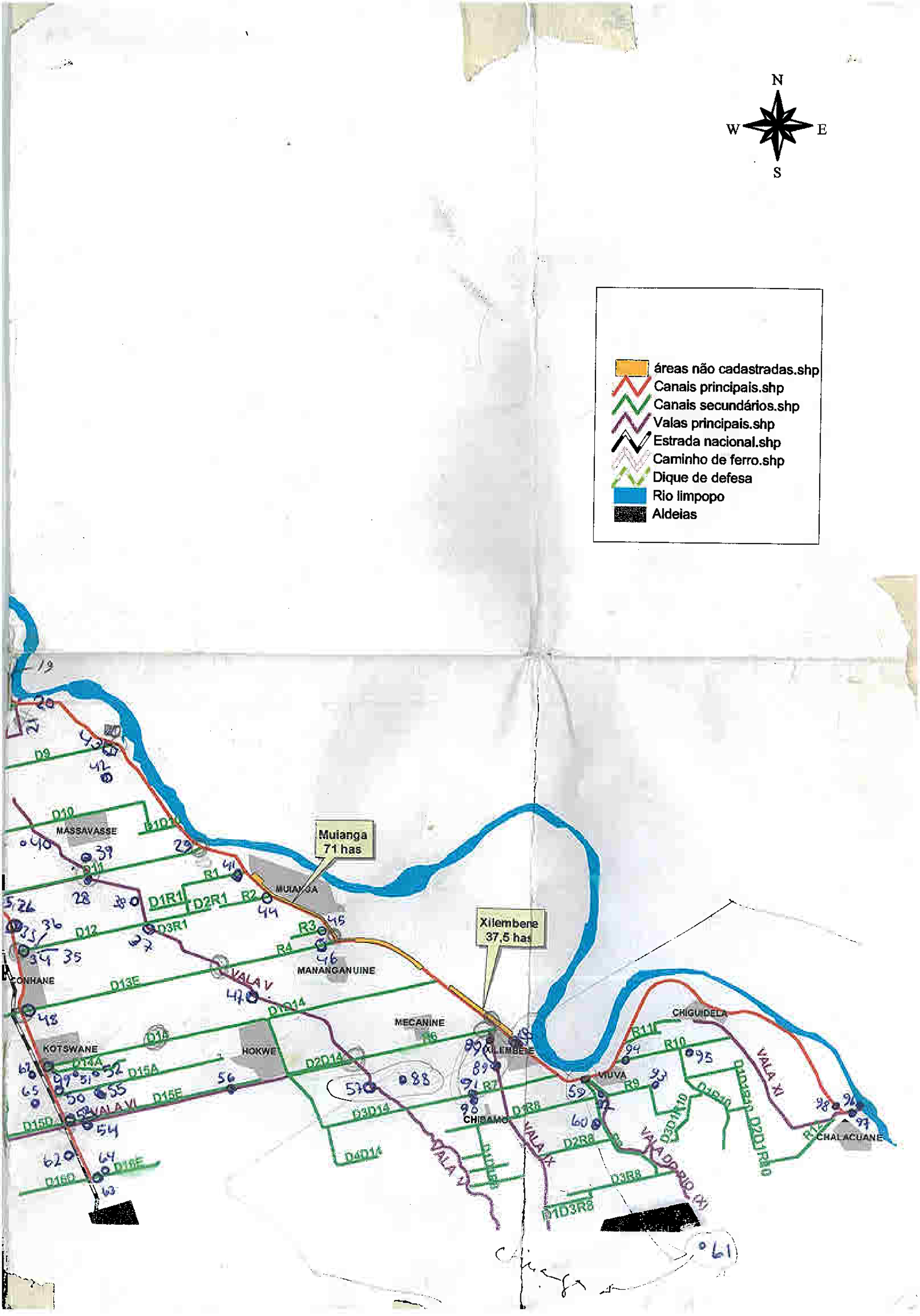
Maio de 2005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Caminho de ferro.shp
Dique de defesa
Rio limpopo
Aldeias
Muianga
71 has
Xilembene
37,5 has
MASSAVASSE
MUIANGA
MANANGANUINE
CONHANE
KOTSWANE
HOKWE
MECANINE
XILEMBENE
CHIBAMO
VIUVA
CHIGUIDELA
CHALACUANE
VALA V
VALA VI
VALA IX
VALA XI
VALA DO RIO (X)
D9
D10
D11
D12
D13E
D15A
D15E
D15D
D16D
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D3D14
D4D14
D1R1
D2R1
D3R1
D1R8
D2R8
D3R8
D1D3R8
R1
R2
R3
R4
R7
R9
R10
R11
R12

5SUPPLEMENT 2

St.	Coordinates	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	NO_2-(LR)	PO4	O2
1 (1)	S24°24'10.4" Eo32°52'05.8"	7.6 09.30	20.4	508 µs	8.2	7	28.6 07.50	17	438 µS	8.42	9	0.013 mg/L	2.8 mg/L	7.4 mg/L
1 (2)	S24°24'10.4" Eo32°52'03.1"	7.6 09.35	20.6	516 µs	8.15	4								
2 (1)	S24°24'12.6" Eo32°52'03.1"	7.6 09.45	24	506 µs	8.25	9								
2 (2)	S24°24'12.6" Eo32°52'03.1"	7.6 09.50	23	510 µs	8.25	6								
3 (1)	S24°24'55.9" Eo32°51'37.8"	7.6 10.05	18	527 µs	8.24	8	28.6 07.55	20	454 µS	8.27	10			
3 (2)	S24°24'55.9" Eo32°51'37.8"	7.6 10.10	18	504 µs	8.27	9								
4	S24°25'39.1" Eo32°51'38.0"	7.6 10.25	24.2	364 µs	7.4	5	28.6 08.15	16.4	394 µS	7.08	4	0.007 mg/L	1.5 mg/L	4.3 mg/L
5 (1)	S24°26'23.4" Eo32°52'11.4"	7.6 10.35	23.4	518 µs	8.25	11	28.6 08.25	20.2	467 µS	8.10	12			
5 (2)	S24°26'23.4" Eo32°52'11.4"	7.6 10.40	23.4	527 µs	8.24	9								
6	S24°28'09.4" Eo32°53'40.3"	7.6 10.50	20.8	447 µs	8.3	5	28.6 08.40	19.2	471 µS	8.26	11	0.006 mg/L	0.9 mg/L	8.1 mg/L
7	S24°28'25.2" Eo32°56'38.3"	7.6 11.00	26	447 µs	8.28	11	28.6 08.50	18.2	474 µS	8.29	11	0.003 mg/L	0.8 mg/L	8.3 mg/L
8	S24°28'30.6" Eo32°57'05.6"	7.6 11.10	22.4	487 µs	7.53	83	28.6 09.05	18.4	484 µS	7.50	12	0.001 mg/L	0.6 mg/L	5.6 mg/L
9	S24°28'54.3" Eo32°58'12"	7.6 11.25	20.4	444 µs	8.36	11	28.6 09.20	16.4	472 µS	7.92	6	0.001 mg/L	0.7 mg/L	7.6 mg/L
10	S24°31'14.3" Eo33°00'16.9"	7.6 11.35	19	766 µs	7.47	0	28.6 09.50	19.4	773 µS	7.64	4			

St.	Coordinates	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	NO_2^- (LR)	PO4	O2
11 (1)	S24°31'26.7" Eo33°00'16.1"	7.6	20	444 µs	8.31	2	28.6 10.00	18.2	476 µS	8.30	7	0.001 mg/L	0.6 mg/L	7.9 mg/L
11 (2)	S24°31'26.7" Eo33°00'16.1"	7.6	21	448 µs	8.36	1								
12	S24°32'04.1" EO33°02'04.0"	8.6	16	774 µS	7.54	11	28.6 10.05	17.8	789 µS	7.42	1	0.004 mg/L	1.5 mg/L	4.4 mg/L
13	S24°32'40.6" EO33°02'55.0"	8.6	19	709 µS	7.73	0	28.6 10.25	20.2	664 µS	7.49	1	0.001 mg/L	0.9 mg/L	5.6 mg/L
14 (1)	S24°33'31" EO33°03'04"	8.6	19.4	1406 µS	8.83	3	28.6 10.40	17.4	1852 µS	7.79	9	0.008 mg/L	0.6 mg/L	5.8 mg/L
14 (2)	S24°33'32" EO33°03'03"	8.6	19	1376 µS	8.15	5								
15	S24°33'58.5" EO33°02'54.2"	8.6	15	401 µS	8.64	3	28.6 10.50	16.4	453 µS	8.61	3			
16	S24°33'52.4" EO33°01'04.0"	8.6	21	398 µS	8.35	0	28.6 11.05	19.2	470 µS	8.37	8			
17	S24°33'33.5" EO33°00'42.2"	8.6	19.4	463 µS	7.88	22	28.6 11.15	20.2	481µS	7.89	6	0.001 mg/L	0.6 mg/L	7.7 mg/L
18	S24°34'10.5" EO33°04'23.2"	8.6	20	433 µS	8.04	0								
19	S24°34'38" EO33°04'48"	8.6	17	502µS	7.7	0	28.6 12.10	16.8	548µS	7.20	1	0.001 mg/L	0.5 mg/L	4.3 mg/L
20	S24°35'08.8" EO33°05'24.6"	8.6	20.4	441 µS	8.37	0	28.6 11.55	18.4	476 µS	8.50	3	0.004 mg/L	0.4 mg/L	9.5 mg/L
21	S24°35'10.8" EO33°05'20.7"	8.6	19.4	418 µS	7.68	3								
22	S24°35'58.4" EO33°04'06.2"	8.6	21.6	666 µS	8.24	4								

St.	Coordinates	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	NO_2^- (LR)	PO4	O2
21	S24°35'10.8" EO33°05'20.7"	8.6 11.15	19.4	418 µS	7.68	3								
22	S24°35'58.4" EO33°04'06.2"	8.6 12.10	21.6	666 µS	8.24	4								
23	S24°35'23.5" EO33°03'55.6"	8.6 12.25	20.8	427 µS	8.33	0	28.6 11.40	19.0	473 µS	8.32	6	0.001 mg/L	0.4 mg/L	7.9 mg/L
24	S24°36'31.1" EO33°04'13.8"	8.6 12.40	21.4	434 µS	8.3	1	29.6 11.05	20.2	463 µS	8.32	5	0.019 mg/L	2.0 mg/L	7.9 mg/L
25	S24°38'40.8" EO33°04'47.1"	8.6 12.55	20.2	459 µS	8.35	0	29.6 09.25	19.6	473 µS	8.35	3	0.003 mg/L	0.5 mg/L	8.3 mg/L
26	S24°38'40.8" EO33°04'13.8"	8.6 13.00	19.2	1883 µS	7.87	1								
27	S24°38'35.8" EO33°04'31.6"	8.6 13.15	22.6	444 µS	8.32	0								
28	S24°38'19.6" EO33°07'01.4"	8.6 13.40	20.2	1863 µS	7.73	1	29.6 09.50	19.2	1907 µS	7.81	2	0.002 mg/L	0.6 mg/L	7.1 mg/L
29	S24°37'42" EO33°09'06.6"	8.6 14.25	20.8	402 µS	7.6	0	29.6 10.05	17.0	459 µS	7.20	1	0.001 mg/L	0.5 mg/L	4.8 mg/L
30	S24°35'30.1" EO33°03'55.8"	12.6 09.25	18.2	1100 µS	7.76	55								
31	S24°38'03.1" EO33°04'34.5"	12.6 09.45	18.2	1545µS	8.35	5								
32	S24°38'03.1" EO33°04'34.5"	12.6 09.50	19.2	691 µS	7.96	4								
33	S24°39'05.8" EO33°05'23.6"	12.6 10.10	16.6	631 µS	7.64	3	29.6 11.15	17.5	589 µS	7.30	1	0.001 mg/L	0.6 mg/L	5.3 mg/L
34 (1)	S24°39'38.2" EO33°05'28.9"	12.6 10.30	20.8	511µS	8.34	6	29.6 11.20	20.2	477 µS	8.30	3			

St.	Coordinates	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	NO_2^- (LR)	PO4	O2
34 (2)	S24°39'38.2" EO33°05'28.9"	12.6 10.35	20.8	500 µS	8,33	4								
35	S24°39'33.8" EO33°05'50.4"	12.6 10.45	21	719 µS	7.56	8								
36	S24°39'33.8" EO33°05'50.4"	12.6 10.50	19.8	524 µS	7.5	3								
37	S24°39'05.9" EO33°08'01.2"	12.6 11.15	17.4	483 µS	7.77	2								
38	S24°38'33.7" EO33°07'53.0"	12.6 11.30	17	622 µS	7.65	0								
39	S24°38'05.9" EO33°06'55.3"	12.6 11.45	24.4	2.95mS	7.53	0								
40	S24°38'04.3" EO33°04'59.6"	12.6 12.00	23.2	90.86mS	8.67	0								
41	S24°38'06.9" EO33°09'57.7"	12.6 12.35	21.6	522 µS	7.75	2	02.07 12.20	17.6	474 µS	8.44	4	0.003 mg/L	0.4 mg/L	
42	S24°36'25.8" EO33°07'23.4"	12.6 13.05	16.4	489 µS	7.63	1	29.6 10.40	20.2	480µS	7.99	3	0.002 mg/L	0.5 mg/L	7.2 mg/L
43	S24°35'50.5" EO33°07'21.2"	12.6 13.25	20.8	440 µS	8.65	8								
44	S24°38'33.9" EO33°10'29.9"	12.6 14.00	22.6	482µS	8,49	10	02.07 12.15	18.8	477 µS	8.28	5	0.001 mg/L	0.3 mg/L	
45	S24°39'08.8" EO33°11'37.5"	12.6 14.25	21	450 µS	8.56	6								
46	S24°39'24.2" EO33°11'43.9"	12.6 14.45	19.8	489 µS	8.57	0	02.07 11.50	19.0	740 µS	8.46	2	0.001 mg/L	0.3 mg/L	
47	S24°40'16.3" EO33°10'10.1"	12.6 15.10	22	1446 µS	8,85	0	02.07 11.35	24.4	1457 µS	7.63	4	0.002 mg/L	1.2 mg/L	

St.	Coordinates	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	NO_2- (LR)	PO4	O2
48	S24°40.747'	13.6					29.6							
	EO33°05.569'	07.20	19.6	535 µS	8.32	3	12.00	19.6	469 µS	8.85	3	0.003 mg/L	0.4 mg/L	5.9 mg/L
49	S24°41.740'	13.6					02.07							
	EO33°06.029'	07.40	18.6	509 µS	8.15	2	11.05	18.6	472 µS	8.15	2	0.002 mg/L	0.5 mg/L	
50	S24°42.264	13.6												
	EO33°06.258'	08.00	18.0	539 µS	7.36	11								
51	S24°42.138'	13.6												
	EO33°06.275'	08.15	19.8	63.86 mS	8.89	5								
52	S24°42.208'	13.6												
	EO33°06.446'	08.25	16.4	1502 µS	7.81	0								
53	S24°42.756'	13.6												
	EO33°06.492'	08.45	18.8	469 µS	7.96	4								
54	S24°42.726'	13.6					29.6							
	EO33°06.535'	09.00	16.8	906 µS	7.63	2	11.45	19.2	456 µS	7.98	3	0.001 mg/L	0.5 mg/L	8.7 mg/L
55	S24°42.661'	13.6												
	EO33°06.542'	09.05	18.4	78.96 mS	7.96	7								
56	S24°42.029'	13.6					02.07							
	EO33°09.737'	09.40	18.8	989 µS	7.55	6	10.40	17.4	984 µS	7.34	4	0.001 mg/L	0.7 mg/L	
57	S24°42.007'	13.6					02.07							
	EO33°12.539'	10.10	17.0	1279 µS	7.51	2	10.25	17.2	1419 µS	7.29	3	0.002 mg/L	0.8 mg/L	
58	S24°41.293'	13.6					02.07							
	EO33°15.667'	10.35	21.6	498 µS	8.43	3	09.55	18.4	470 µS	8.38	2	0.001 mg/L	0.6 mg/L	
59	S24°41.836'	13.6					02.07							
	EO33°16.801'	10.55	21.6	485 µS	8.56	5	08.45	18.2	444 µS	4.80	4	0.004 mg/L	0.6 mg/L	
60	S24°42.497'	13.6					02.07							
	EO33°17.137'	11.15	22.8	484 µS	7.4	3	08.35	17.0	450 µS	7.34	6	0.003 mg/L	1.8 mg/L	
61	S24°45.198'	13.6					02.07							
	EO33°17.300'	11.45	20.8	988 µS	8.03	1	08.15	19.2	1106 µS	8.21	10	0.001 mg/L	0.5 mg/L	

St.	Coordinates	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	NO_2^- (LR)	PO4	O2
62	S24°43'15.9" EO33°06'44.2"	15.6 08.40	15.8	538 µS	7.51	0								
63	S24°43'55.8" EO33°06'58.8"	15.6 08.50	20.2	468 µS	8.08	5	29.6 11.50	19.8	447 µS	8.11	3	0.002 mg/L	0.4 mg/L	7.9 mg/L
64	S24°43'43.3" EO33°07'02.1"	15.6 08.55	19.2	561 µS	7.45	0	29.6 11.55	18.8	576 µS	7.28	1	0.001 mg/L	0,4 mg/L	3.7 mg/L
65	S24°42'30.5" EO33°05'54.3"	15.6 09.15	17.4	600 µS	7.52	0								
66	S24°42'49.1" EO33°05'16.3"	15.6 09.35	17.6	500 µS	7.48	1								
67	S24°43'73.2" EO33°03'07.8"	15.6 10.15	16.4	514 µS	7.29	5								
68	S24°43'15.5" EO33°04'06.0"	15.6 10.25	21.8	892 µS	7.48	4								
69	S24°42'52.9" EO33°05'54.6"	15.6 10.50	21.6	88.16 mS	7.90	5								
70	S24°40'21.9" EO33°03'30.0"	15.6 11.10	18.2	855 µS	7.81	1								
71	S24°36'50.1" EO33°02'29.9"	18.6 07.35	15	508 µS	8.25	8	29.6 07.20	16.8	459 µS	8.14	4	0.015 mg/L	1.6 mg/L	7.4 mg/L
72	S24°38'08.0" EO33°02'15"	18.6 08.00	15.8	539 µS	7.35	2	29.6 08.39	17.2	1638 µS	7.44	3	0.001 mg/L	1.2 mg/L	5.2 mg/L
73	S24°38'08.0" EO33°02'15"	18.6 08.05	17.6	502 µS	7.98	7								
74	S24°38'38.9" EO33°02'20.8"	18.6 08.15	13.6	651 µS	7.58	4								
75	S24°39'09.3" EO33°02'31.0"	18.6 08.35	21.4	1109 µS	7.61	8	29.6 08.55	19.0	711 µS	7.17	1	0.003 mg/L	0.9 mg/L	2.4 mg/L

St.	Coordinates	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	Date/-Time	Temp. °C	Conduc-tivity	pH	Turbi-dity	NO2-(LR)	PO4	O2
88	S24°41'53.3" EO33°13'11.3"	19.6 07.45	15.8	675 µS	7.66	4								
89	S24°41'35.2" EO33°15'02.9"	19.6 08.05	17.0	525 µS	7.58	2	02.07 10.05	18.0	518 µS	7.66	6	0.002 mg_/L	0.6 mg/L	
90	S24°42'01.8" EO33°15'02.6"	19.6 08.40	15.6	555 µS	7.57	1								
91	S24°42'01.8" EO33°15'02.6"	19.6 08.45	18.4	495 µS	7.71	3	02.07 10.12	18.8	478 µS	7.64	1	0.001 mg/L	0.5 mg/L	
92	S24°41'56.8" EO33°17'04.2"	19.6 09.15	18.2	483 µS	7.50	4	02.07 09.45	18.6	523 µS	7.13	1	0.001 mg/L	0.6 mg/L	
93	S24°41'54.3" EO33°18'10.7"	19.6 09.40	17.0	531 µS	7.64	2								
94	S24°41'30.3" EO33°17'28.7	19.6 10.00	20.2	484 µS	8.57	4	02.07 08.50	17.4	468 µS	8.66	3	0.001 mg/L	0.5 mg/L	
95	S24°41'21.4" EO33°18'13.8"	19.6 10.15	19.2	521 µS	9.26	20								
96	S24°42'13.8" EO33°22'23.8"	19.6 10.45	20.8	864 µS	8.43	14	02.07 09.15	22.4	745 µS	7.70	9	0.003 mg/L	0.9 mg/L	
97	S24°42'18.2" EO33°22'02.1"	19.6 11.05	20.4	535 µS	7.5	28	02.07 09.20	18.8	513 µS	7.36	3	0.002 mg_/L	1.0 mg/L	
98	S24°42'19.2" EO33°21'56.5"	19.6 11.15	20.6	490 µS	8.64	2	02.07 09.25	17.6	469 µS	8.50	5	0.003 mg/L	0.6 mg/L	

SUPPLEMENT 3

RESEARCH DIARY

June 7th, 2007, weather: sunny and slight wind
We started the research today. First some planning in the morning. Then we drove to the river and started to take the samples.

Site 1. Three samples were taken from the upper course. The station is located to the north from dam Marracetane. Area looked very arid. On the right side were little if any plantation and pasture. On the left side were local settlements. The channel was cleaned up from water plants which speed up flowing.

Site 2. Two samples were taken from a main channel. The samples were taken from both sides of channel. The station is the same as site 1 but the samples were taken on the other side of little dam.

Site 3. Two samples were taken from main channel. Across the main channel goes two bridges, another for the cars and another for the train. The samples were taken on the bridge of train.

Site 4. One sample was taken from the lake what locates in the middle of the cultivated land. The water in the lake is used for drinking, washing and to irrigate the fields. The sample was taken from the shore of the lake.

Site 5. One sample was taken from the main channel. There was a bridge for the cars. The sample was taken on the bridge in the middle of the channel.

Site 6. One sample was taken from the main channel. The sample was taken on the dam in the middle of channel.

Site 7. One sample was taken from a small irrigation channel. Water comes to the channel from the main channel. The sample was taken from the beginning of the channel. Water was very well mixed.

Site 8. One sample was taken from drainage channel VALA I. The channel was quite arid and there were lots of water plants.

Site 9. One sample was taken from a small irrigation channel. The sample was taken from the same irrigation channel where we took sample 7 but station was further away in the plantations. In the station there was a small walk-way bridge and plenty of water plants. Near to the channel was a bulwark which protects plantations at flooding time.

Site 10. A sample was taken from the drainage channel VALA I. The channel was the same as at station 8. In the channel was plenty of water plants but also more water than station 8. Water was very clear because of excess of water plants.

Site 11. Two samples were taken from the main channel. The station is close to Chokwé village. The samples were taken from a bridge where there were lots of traffic. People were also fishing on the bridge

June 8th, 2007, weather: sunny and slight wind

Site 12. Sample was taken from the drainage channel VALA I. The channel is overgrown. Round the channel are lots of plantation, pastures and wasteland.

Site 13. Irrigation systems one exit point. At that moment and this point Limpopo River was torrid. This removal point belongs at river and there was some water. There were lots of plants where we found water, otherwise landscape was only a torrid river bed. Sample's water was mixed well because of flowing was hard.

Site 14. Two stations, both stations were basins which gets water from a drainage channel Vala II. From here water goes back to the river. Around the basins were plantations and another side at the basins were torrid river bed. On the water growned some water plants and another basin lived a crocodile

Site 15. The channel is approximately 1,5 meter wide irrigation channel D6A. Around the channel were lots of plantations. The sample was taken from the channel's exit point. There were not so much water plants but we though that channel was cleaned.

Site 16. A sample was taken from the same irrigation channel as we took sample 15 but from the end of the channel (D6A). At this point the channel is combined to the main channel. There were plenty of water plants.

Site 17. The channel is the same as station 14. Water was turbid including lots of vegetation and soil.

Site 18. Partly torrid drainage channel VALA III. Water in the channel was very clear because of water stands and there was many water plants. Around the channel were plenty of plantations.

Site 19. One of the drainage channels to the Limpopo River (VALA III). Water smelled very bad, on the stones growned all kinds of algas and around the channel were lots of plantations, bushy fields and pastures

Site 20. This irrigation channel D8 is overgrown. Another side of the channel was plenty of plantations and on another side were arid fields and arid pastures. The channel is close to the another main irrigation channel

Site 21. A station is in the middle of fields. This channel is a drainage channel VALA IV, it was quite narrow. The channel was full of high meadow. A sample was taken apparently from the laundry place.

Site 22. This sample was taken because of it was a same channel as station 21 had. This station was taken from another point of channel. In the channel were lots of water plants.

Site 23. A sample was taken at the beginning of the irrigation channel D8. There were lots of water plantations. A flowing was powerful, that's why the water was mixed well. Around the channel were lots of fields. On another side to the channel was a main road. The channel D8 locates close to Lionde village.

Site 24. One sample was taken from the irrigation channel D9. In the channel were lots of water plants.

Site 25. A water flows from the main channel to the irrigation channel D11. A sample was taken from the beginning of the channel. In the irrigation channel growned plenty of water plants.

Site 26. The sample was taken from the anonymous little channel.

Site 27. The sample was taken from the irrigation channel D10.

Site 28. The biggest and the most dangerous drainage channel VALA V. In the channel were lots of water plants and aquatic animals. The water was very clear because of water plants and water standed. This channel is creature's watering place and around the channel were companies' plantations. The sample was taken on the bridge in the middle of channel.

Site 29. One sample was taken from the irrigation channel D11. Around the channel were lots of fields.

June 12th, 2007, weather: sunny and moderate wind

Site 30. One sample was taken from drainage channel. The channel locates near village Chipapa. Water looked brown and dirty. On the surface were lots of water plants.

Site 31. One sample was taken from a little lake which was not connected to the irrigation system.

Site 32. One sample was taken from the same drainage channel as sample 30. Water looked clear.

Site 33. One sample was taken from the drainage channel. In the channel were lots of water plants.

Site 34. Two samples were taken from an irrigation channel D12. Colour of water was brown to green. On the surface in the water was not water plants but the banks were very bushy.

Site 35. One sample was taken from drainage channel. Water looked dirty and shore was full of vegetation.

Site 36. One sample was taken from drainage channel. On the surface were lots of little water plants.

Site 37. A sample was taken from the crossing of two drainage channels (VALA V and a smaller drainage channel). In the channel was lots of water plants.

Site 38. One sample was taken from drainage channel. There were not lots of water plants and water looked quite clean.

Site 39. One sample was taken from the pool in the middle of field. The station is near village Massavasse.

Site 40. One sample was taken from the pool in the middle of field. Water was very salty.

Site 41. On sample was taken from drainage channel. The station was near of main channel. In the channel were lots of water plants.

Site 42. One sample was taken from drainage channel. The channel was full of vegetation.

Site 43. One sample was taken from the bushy drainage channel.

Site 44. One sample was taken from little irrigation channel R2. The station was near to village Muianga.

Site 45. One sample was taken from the irrigation channel R3. In the channel were lots of water plants.

Site 46. Sample was taken from the irrigation channel R4. The channel was close to village Mananganuine. In the channel were lots of water plants.

Site 47. A sample was taken from a big drainage channel VALA V. The sample was taken from a close to bridge which goes over the channel. In the channel was plenty of ground cover but couple years ago it has been totally clear.

June 13th, 2007, weather: sunny and slight wind

Site 48. A sample was taken from the crossing of two irrigation channels (D13 and a main channel). The channels were quite big and clean, only some water plants. The channels located close to Conhane village. The sample was taken from the beginning of channel D13.

Site 49. A sample was taken from the crossing of two irrigation channels (A main channel and D14). A place located close to Kotswane village. The channel was full of water plants.

Site 50. A sample was taken from a drainage channel which is next to channel D15A. The channel was full of bushes and water was dirty.

Site 51. One sample was taken from pool which is not connected to the irrigation system. Water was very salty.

Site 52. One sample was taken from drainage channel. Water looked very clear.

Site 53. A sample was taken from the crossing of two irrigation channels (A main channel and D15E). The channel was full of water plantation. The sample was taken at the beginning of channel D15E.

Site 54. Sample was taken from the drainage channel. The channel is overgrown.

Site 55. Sample was taken from the pool which is not connected to the irrigation system.

Site 56. A sample was taken from the crossing of irrigation channel and drainage channel (VALA VI). The station located close to Hokwé village. Water was very clear and the channel was deep. In the channel was some of water plants and there was not a ground cover.

Site 57. Sample was taken from drainage channel VALA V. Water looked clear and the velocity was high.

Site 58. A sample was taken from a main channel. A station located close to Xilembene village. In the channel water flows very well, there was not many water plants but there was a bit ground cover.

Site 59. A sample was taken from a small irrigation channel R8. The station is close to Viuva village. The channel was very bushy and water looked greenish.

Site 60. Sample was taken from a drainage channel which goes close to irrigation channel R8. In the channel were lots of water plants. Water in the channel looked quite clear.

Site 61. A sample was taken from a little lake, which located in southern side of irrigation system. The lake got water from the drainage channels. Water in the lake was quite clear, there was not a ground cover but the banks were reeds. The lake was close to Malhazene village.

June 14th, 2007, weather: sunny and slight wind

Site 62. Sample was taken from drainage channel. In the channel were lots of high meadows.

Site 63. Sample was taken from irrigation channel D16E. The site is near to village Mapapa. Water looked dirty.

Site 64. Sample was taken from a drainage channel. In the channel were lots of high vegetations.

Site 65. Sample was taken from drainage channel. On the surface were lots of water plants.

Site 66. Sample was taken from drainage channel. In the channel were lots of water plants.

Site 67. A sample was taken from an irrigation channel D13D. Village Nwachicoluane is pretty close, we could hardly saw it. In the channel were bit water and some water plants.

Site 68. A sample was taken from a quite big drainage channel VALA VIII. In the channel were lots of high water plants.

Site 69. Sample was taken from small pool in the middle of fields. Water was very salty.

Site 70. Sample was taken from the drainage channel. Water is low, few water plants and the water was quite clear.

June 18th, 2007, weather: sunny and slight wind

Site 71. One sample was taken from the irrigation channel N2.

Site 72. One sample was taken from drainage channel. In the channel were lots of water plants.

Site 73. Sample was taken from a small irrigation channel which goes from channel D3N to the big drainage channel VALA VII. The station was quite bushy.

Site 74. Sample was taken from a small drainage channel which located in among of irrigation channel D3N and a huge drainage channel VALA VII. In the channel were lots of reeds and it was difficult to find water. Water was dirty.

Site 75. Two samples were taken from a big drainage channel VALA VII. The drainage channel was very wide. In the channel were some water plants and ground cover.

Site 76. Sample was taken from drainage channel. In the channel were lots of water plants.

Site 77. A sample was taken from an irrigation channel D3N. In the station was a curve where the water flows to the smaller anonymous irrigation channel.

Site 78. Sample was taken from drainage channel. Water in the channel looked dirty.

Site 79. Sample was taken from irrigation channel N4. The station locates near to village Nwachicoluane.

Site 80. A sample was taken at the beginning of drainage channel VALA VII. There were high water plants. The channel was very wide.

Site 81. Sample was taken from irrigation channel N4.

Site 82. One sample was taken from pool which is not connected to the irrigation system.

Site 83. Sample was taken from the irrigation channel. In the channel were lots of water plants.

Site 84. Sample was taken from the drainage channel. In the channel were not lots of water plants.

Site 85. Sample was taken from drainage channel. The soil might were very salty.

Site 86. Sample was taken from irrigation channel D1N2. In the channel were not much water plants.

Site 87. Sample was taken from drainage channel. In the channel were lots of meadows.

June 19th, 2007, weather: partly cloudy and hard wind

Site 88. Sample was taken from the drainage channel.

Site 89. Two samples were taken from drainage channel VALA IX. In the channel is good velocity of water.

Site 90. Sample was taken from drainage channel. In the channel were lots of high meadows.

Site 91. Sample was taken from irrigation channel R7. In the channel was not much of water.

Site 92. Sample was taken from drainage channel VALA DO RIO(X). The channel is very wide and bushy.

Site 93. Sample was taken from little drainage channel. In the channel was some low vegetation.

Site 94. A sample was taken from an irrigation channel R10. There were not so much water plants, only on the side of channel.

Site 95. Sample was taken from pool in the middle of field.

Site 96. Sample was taken from the Limpopo River just behind the drainage channel VALA XI.

Site 97. Sample was taken from drainage channel VALA XI. The sample was taken near from the Limpopo River where we could find water. The drainage channel not comes to the river at that moment. In the channel were lots of water plants. Local people gave water to drink their cattle there.

Site 98. Sample was taken from main channel. In the channel was good velocity of water.