Final Project Report for

2016 START Grants for Global Change Research in Africa

Project Title

Water Security in Windhoek: governance, water demand and supply, and livelihoods in the context of urbanization and climate change

Abstract

Governance
In the study, UJAMS Waste Water Treatment Plant (UWWTP) served as a case study to investigate governance and policy analysis in relation to water security in the city of Windhoek. The study revealed that there are different actors that were involved in discussion and decision making to address the issue of water supply to industries, pollution from industrial effluent and the need to find diverse alternatives to the water insecurity problem that ultimately led to establishment and operation of the (UWWTP)
Analysis of Water Management Plan for City of Windhoek 2017 and Transformational Strategic Plan (2017-2022) for City of Windhoek policies revealed that despite being developed recently after the Namibia Climate Change Policy, Strategy and Action Plan had been enacted, very little climate change related issues are mainstreamed and used in these policies despite Windhoek.

Water demand and supply
In central Namibia, where the Capital Windhoek is hosted, water is very scarce. To cope with the effect of drought, water is transferred from Kombat Karst Aquifer and Von Bach and Swakoppoort dam on the Swakop River. The effect of drought on the Swakop River is not well known. To understand the effect of drought, streamflow, and rainfall data from 1969 to 2016 were collected and analyzed using drought indices such as Standardized Precipitation Index (SPI) and Streamflow Drought Index (SDI). It was found that, drought periods were not continuous and a wet period was always followed. The monthly streamflow data for the Swakop river indicate that the river runs dry for most months. Increase in water demand could be affected by prevalence of drought.

Livelihoods
This research component assessed synergetic links between urban households' water security, livelihood and food security among different social groups in the City of Windhoek. The linkage between livelihoods and water security followed a quantitative study based on a sample of 863 households across Windhoek were evaluated with a detailed questionnaire. Main livelihoods include retailing and production. Livelihoods were found to be strongly associated on household

and economic water security, particularly in poor neighbourhoods where water-related livelihoods were common. Water shortage, deteriorating water quality and waste water disposal were factors that impacted negatively on sustaining livelihoods.

Project Information

This section presents contact details of the Principal Investigator and Co-investigators, the names of other investigators, including students

1. Principal Investigator

Mfune, John Kazgeba
Department of Biological Sciences
University of Namibia, P/Bag 13301,
Windhoek, Namibia
jmfune@unam.na / jkmfune@gmail.com

2. Co-investigator #1

Kazembe, Lawrence
Department of Statistics and Population Studies
University of Namibia, P/Bag 13301,
Windhoek, Namibia
lkazembe@unam.na

3. Co-investigator #2

Sirunda, Johannes
NAMWATER, P.0. Box 32237, Pioneers Park
Windhoek, Namibia
sirundaj@namwater.com.na

4. Co-investigator #3

Lewis, Earl
Multi-disciplinary Research Centre (MRC)
University of Namibia, P/Bag 13301,
Windhoek, Namibia
elewis@unam.na

5. Other Co-investigator(s):

(a) **Nickanor**, Ndeyapo
Senior Lecturer, Statistics and Population studies
University of Namibia, Department of Statistics and Population Studies
Email: nnickanor@unam.na /ndeyaponickanor@yahoo.com;
Cell: +264 812550585

(b) **Makuti**, Olavi
Environmental Specialist
City of Windhoek

P.O. Box: 27488, Windhoek
Cell:+264 811405033, E-mail: olavi.makuti@gmail.com / Olavi.Makuti@windhoekcc.org.na

(c) **Iiputa,** Gerhard. [MSc student registered in Dept. Biological Sciences, University of Namibia]
Technologist
Biological Sciences Department; University of Namibia Private Bag 13301, Windhoek, Tel. +264 61 206 4832, Cell. +264 81 263 2198
E-mail: giiputa@unam.na

The total amount of START Funding awarded during the entire funded period of this project from February 2017 to April 30m 2018 was US$: **44,822.1**

1.0 Introduction

1.1 Background information

Namibia, like many countries in semi-arid areas, is characterized by high climatic variability in the form of persistent droughts, unpredictable and variable rainfall patterns leading to scarcity of water (Government of the Republic of Namibia, 2011). Coupled with rapid urbanization, the threats of persistent water scarcity are real. A growing concern is the city of Windhoek, with an urbanization rate of 3.1% per annum. This surge in the population has created many problems for urban planning and vulnerabilities such as water shortage, energy problems, poor sanitation and waste management and related health problems. The city of Windhoek is charged with the responsibility for urban planning but is constrained or challenged by the high influx of people from rural areas. Water security-defined as an acceptable level of water-related risks to humans and ecosystems, coupled with availability of water of sufficient quantity and quality to support livelihoods, national security, human health and ecosystem services (Bakker, 2012; Cook and Bakker, 2012), has manifested in the city of Windhoek. Among others, the persistent droughts and the unpredictable and variable rainfall patterns, due in part to climate change, adversely affects the availability and supply of acceptable quantities and quality of water to the city of Windhoek. This is exacerbated by the high rate of urbanization. Hence there is a strain on service delivery, including water supply, land and infrastructural development. Although quantity and quality of water supply are central to water security (Cook and Bakker, 2012), water governance has a central role in the issue of water security. Bakker (2003) defined water governance as *"the range of political, organizational and administrative processes through which community interests are articulated, their input is incorporated, decisions are made and implemented, and decision-makers are held accountable in the development of service delivery and management of water resources and delivery of water services*". It is evident therefore that the issue of water security, with its many facets, is very central to water issues in the city of Windhoek that range from water and related policies, water supply, water governance, livelihoods, urbanization and climate change to cite a few.

1.2 Research goal and objectives

The study was developed in support of the FRACTAL Project which aims at generation, understanding and incorporation of climate change information into urban decision-making in southern African Cities including the City of Windhoek. The project focused on three areas:- water governance, influence of drought on water resources that supply water to the city of Windhoek and modelling of hotspots of water demand and supply in the context of climate change and urbanization in the city of Windhoek. Objectives of the study are oitlines below, for the three project components.

1.2.1 Water Governance: a case study of processes, actors and timelines at the city of Windhoek Industrial Effluent Water Reclamation Plant.

(a) Analysis of governance issues through a case study of the Ujams Waste Water Reclamation Plant
(b) Assess the extent to which climate change considerations, including the Namibia Climate Change Policy, have been or are being incorporated during planning and implementation of Ujams Waste Water Reclamation Plant by reviewing some relevant policies.

1.2.2 Impact of drought on water resources used for supply to the City of Windhoek

(a) Quantify the severity and duration of drought in Windhoek.
(b) Determine if water supply sources and assumptions in Windhoek is sufficient and appropriate to meet the growing water demand and how climate change and urbanization affect this process.

1.2.3 Water Security and Livelihoods in Windhoek: modeling synergies and hotspots of water demand and supply in the context of climate change and urbanization

(a) Assess the synergetic links between livelihoods and water security, and subsequent food security amongst different social groups in the City of Windhoek.
(b) Investigate the spatial distribution of hotspots accumulating from water supply and demand in Windhoek and how this changes in context of urbanization and climate change.

1.3 Scientific significance and rationale for the research

1.3.1 Water Governance: a case study of UJAMS Windhoek Industrial Effluent Water Reclamation Plant

Broto et al (2015) defined city governance as ‘the multiple ways through which diverse actors intervene in controlling and managing the city’. Similarly, Peyroux et al, (2014; 2017) referred to governance as the many ways civil society, and public and private institutions manage and transform the space within which they live. In the FRACTAL project, it is specifically the governance of water, energy and climate change in relation to development that is of interest (Scott, 2017). Hence for this study, water governance refers to ways in which many actors intervened and interacted which culminated in the establishment and now in the operation and management of the UJAMS Windhoek Industrial Effluent Water Reclamation Plant.

The city of Windhoek, in addition to problems of availability and supply of acceptable quantities and quality of water to the city, has water based industries that not only need large quantities or water but some also produce effluent that can cause pollution. The city of Windhoek established the Ujams Waste Water Reclamation Plant (UWWRP) to clean and reclaim industrial wastewater for further reuse for landscape irrigation, industrial water and or indirect discharge into nearby water extraction areas including the Klein Windhoek River. This case study was based on the premise that knowledge of the current policy and decision-making process for the city and the extent to which the present decisions incorporate climate change information and assessment of current water policies, programs and initiatives in the water sector will contribute to the development of effective methodologies for integration of climate information into the city-level decision-making processes in the city of Windhoek. This in turn would contribute to water security that can be applied at the city-wide scale relevant as a value addition to FRACTAL project.

1.3.2 Impact of drought on water resources used for supply to the City of Windhoek

Drought directly impacts on the availability of sufficient and good quality water and hence in turn adversely affects water security**.** For example, due to persistent drought in Namibia, water supply to the dams that supply water to the city if Windhoek and surrounding areas is adversely affected. Reduced volume of water has led increased pollution and high levels of toxic chemicals eutrophication. This has affected the quality of water.

This component of the research project was developed to provide a synthesized baseline data on trends on water quantity on sources of water for Windhoek and other surrounding towns. These data are relevant to understand impacts of drought on the water supply and should inform future designs of water supply infrastructure and current and future decisions regarding water supply and use in the city of Windhoek. The data provide basis for development of drought planning framework for the supply utility as well as the city of Windhoek. These are very relevant to the understanding, and incorporation of climate information into urban decision-making in the city of Windhoek. Outcomes may also be shared with cities in the region that may have similar climate imposed impacts

1.3.3 Water Security and Livelihoods in Windhoek

Water security is a critical element in livability of cities. The changing climate and rapid urbanization will have an impact on the water-stressed cities like Windhoek. The sustainable management of water resources is a pressing environmental challenge in the present century. Understanding how water security may affect or destroy livelihoods could assist in adapting resilient approaches or help in transforming water governance systems.

1.4 How this project complement FRACTAL research

The main focus of the FRACTAL project is to :-advance scientific knowledge on regional climate responses to global change, enhance knowledge on how to integrate this information into decision making at the city-region scale and to contribute to decisions for resilient urban development generate. FRACTAL has adopted an iterative, transdisciplinary, interdisciplinary co-exploration and /or co-production approach.

The GEC START was inspired by and complements FRACTAL research and provides added value to the main focus of FRACTAL as follows:-

(a) The outcome of the policy analysis of water governance (an important facet of water security) issues carried out in the case study of the Windhoek Industrial effluent water reclamation plant will contribute to understanding of the role of policy making and decision-making processes and organizational and administrative processes through which various actors in the reclamation plant express their interests and participate. This analysis of the case study will also reveal power relations amongst actors and how decisions are made in the development and management of water resources. This will then be used to determine the extent to which these case-study specific outcomes reflect what happens at the City-wide scale in terms of water governance in the face of climate change, which is central to the FRACTAL Project.

(b) Water supply and security is a serious issue in Namibia especially the city of Windhoek. Analysis of drought, streamflow, and rainfall data from 1969 to 2016, in the present study, using drought indices such as Standardized Precipitation Index (SPI) and Streamflow Drought Index (SDI) revealed that drought periods were not continuous and a wet period was always followed. This information is useful for future water and other infrastructure and urban development hence aligns well with the aims of the FRACTAL project.

(c) This study added more value to FRACTAL project by assessing the synergetic links amongst water security, livelihoods and resilience in the City of Windhoek. The study showed that livelihoods were found to be strongly associated on household and economic water security, particularly in poor neighbourhoods where water-related livelihoods were common. These results provide supporting and collaborating complementary evidence that informal settlements have inadequate water supply and provision. During the first FRACTAL project Windhoek learning lab in March 2017, water insecurity in informal settlements was flagged as an important “burning issue”. The results of the present study confirms this with empirical data. The study further revealed that water shortage, deteriorating water quality and waste water disposal were factors that impacted negatively on sustaining livelihoods. Water shortage is partly due to impacts of climate change, an important focus for the FRACTAL project.

(d) Lastly but not least, the stakeholder consultative approach and involvement of transdisciplinary research team will conformed to the approach adopted by FRACTAL for co-exploration and co-production of knowledge.

2. Approaches, Methods, Activities and Engagement

2.1 Governance

2.1.1 Analysis of governance issues: Ujams Case study

The governance study employed Scotts (2017) notion of urban governance configuration which looks at the complex arrangements of multi-scalar actors and entanglements of socio-economic, political, and environmental processes shaping urban development and how they come together at a particular time and place in any city. We utilized the following set of elements of the concept of urban governance configuration proposed by Scott (2017) as presented in Table 1 below:-

Table 1. Elements of concept of urban governance configuration (Adopted from Scott, 2017)

	Element	Content
1	Discourses	Language used by actors to frame their interests in any policy arena. There may be multiple discourses that are used to argue by actors for their interests in any decision-making process. Dominant discourses will become institutionalized into policy.
2.	The actors	Multiple, multi-scalar actors – both state and non-state), their resources and the power relations between them.
3	Legislation, Policies and mandates	Legislation, policies that give mandates and power to actors to implement policies.
4	Materialities	Consists of the technologies and platforms (GIS-ITC software and their products), and infrastructure (dams, pipelines, storm water drains) are increasingly important elements of the governance configuration
5	Decision-making processes	Actual work done by actors through their discourses, in deliberating and debating issues and formulating policies
	⇩	⇩
	Implementation of policies and outcomes,	**Examples of outcomes**:- • The building of roads, • The provision of water pipelines to carry water, • Increase of quality of life as residents receive electricity in their homes. • Establishment of Ujams Windhoek Industrial effluent reclamation plant

We visited the UJAMS treatment plant in order to familiarize with the operations of the effluent plant and held discussion with Mr James Villet (UWTC: Plant Superintendent; Process and Research). In addition, we held an interview with Mr Menge a former chief scientist who worked at the city of Windhoek at the time when UJAMS was established. We used semi-structured questionnaire to obtain governance data from actors involved in the establishment and operation of the Ujams Windhoek Industrial Effluent Water Reclamation Plant. Data from the questionnaire and interview were subjected to the urban governance configuration analysis as described in Table 1. In order to assess the efficacy of the UJAMS effluent treatment plant, we obtained data from the city of Windhoek, on content of various compounds in the effluent from NamBreweries, Nam beverages, MEATCO (abattoir) and Nakara Tannery and data for the same compounds after treatment at UJAMS for 2012 to 2017. Concentrations of the following were compiled and compared before and after treatment at the UJams plant:- total potassium and nitrogen (TKN), total suspended solids (TSS), chemical oxygen demand (COD), orthophosphate and conductivity. These were plotted for 2012 and 2013 and for 2016 and 2017. The plant was under construction between 2014 and 2015.

One researcher on the project, Mr Iipuita registered for his MSc in Biology by research. He will undertake research on: “Assessment of the potential uptake of chromium and its effects on growth and development of selected plant species exposed to industrial effluent from Ujams industrial waste water treatment plant in Namibia”. The project proposal is undergoing the University approval process.

2.1.2 Policy analysis

Water Management Plan for City of Windhoek 2017 and Transformational Strategic Plan (2017-2022) for City of Windhoek polies were reviewed in order to assess the extent to which climate change considerations, including the Namibia Climate Change Policy, are incorporated in the Polices and to see if these would be applied during implementation of Ujams Waste Water Reclamation Plant.

The results of the analysis of governance issues for Ujams industrial waste treatment plant and policy analysis of the Water supply and sanitation policy were presented at the stakeholders workshop that was held on 27th April 2018.

2.2 Water demand and supply

2.2.1. Study area

The study was carried out in the Central Area (CAN) water supply network which lies on the Swakop-Omaruru catchment and Omatako-Okavango catchment. The central area water supply network comprises of 3 dams (Swakoppoort, Omatako and Von Bach Dam), groundwater sources and reclamation plant. The Swakop River was selected to assess the impact of both meteorological and hydrological droughts (Figure 1).

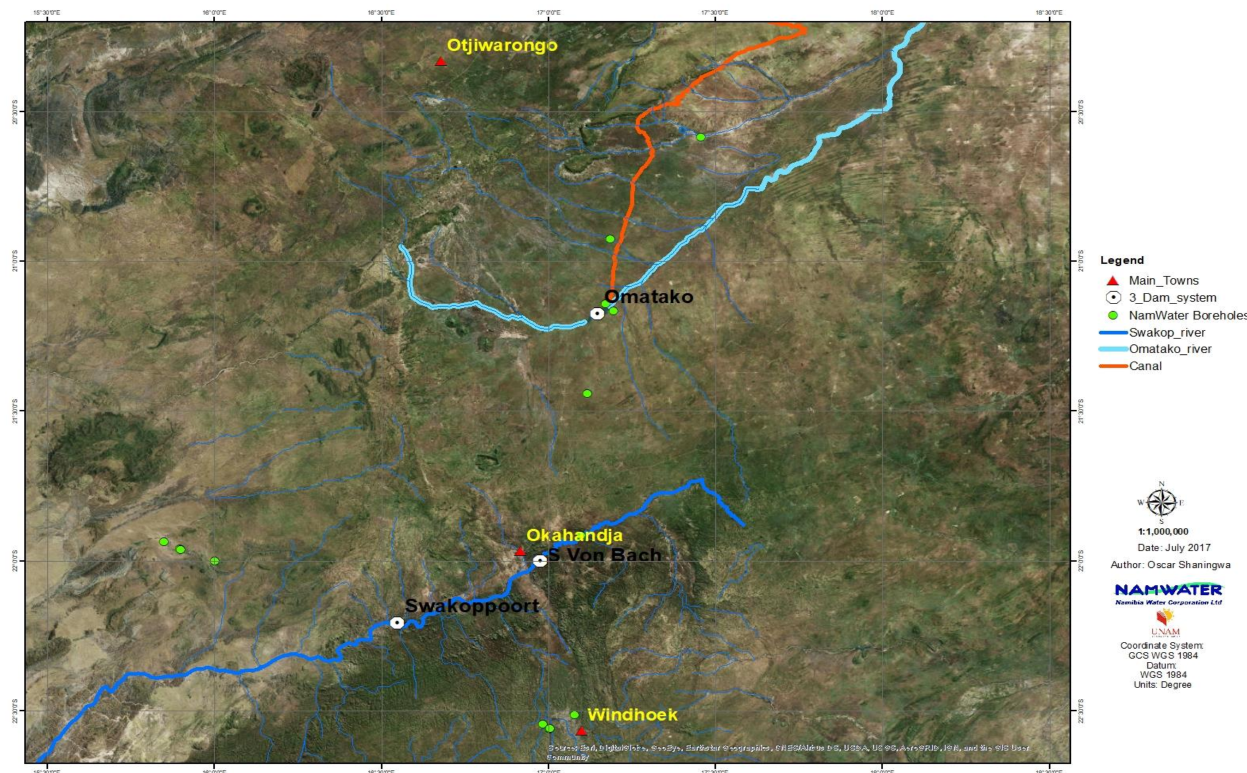


Figure 1: Study area

2.2.2. Approaches

In order to investigate and quantify the impact of drought on the water sources used for supply to Windhoek, current and historical data were obtained and analyzed. Historical hydrological data of streamflow, dam levels, rainfall and groundwater table level were collected and these data were used to identify and characterize drought periods. To analyse the impact of drought the following Drought Indices were used: (a) Standardized Precipitation Index (SPI): to quantify the precipitation deficit for multiple timescales, i.e. from 1969 – 2016. (b) Streamflow Drought Index (SDI): to access drought severity by calculating the runoff streamflow volume data from different time periods, i.e. from 1969 – 2016. (c) A Flow Duration Curve (FDC) was used to characterize the flow regime of a stream. The FDC was constructed using monthly streamflow data from the period 1970 to 2016. Water demand date from 2003-2017 were also collected to determine the increase in water demand over time in Windhoek.

2.2.3. Methods

2.2.3.1. Data collection:

Collection of water quantity and groundwater levels data

Historical water quantity and streamflow data for surface water sources was collected at NamWater, City of Windhoek and the Department of Water Affairs after obtaining their permission to access these data. Historical data from 1977 to date was requested from the above-mentioned offices. The data was for Streamflow for the Swakop River, dam levels, and percentage quantity. Historical data was used for the determination of the duration and severity of drought in the selected study areas.

Collection of water demand data
Water demand data for the Windhoek from 2003-2017 was collected to determine the change in water demand over time.

2.2.3.2. Collection of rainfall data
Mean monthly and annual rainfall from 1977 to 2017 for the central area of Namibia was obtained from the Meteorological Office in Windhoek. Prior to request of these data, rainfall stations that are in the central water supply network were selected and these were Okahandja and Windhoek Stations. These data were used to determine duration and severity of drought.

2.2.3.3. Data Analysis
2.2.3.3.1. Streamflow drought analysis
Firstly, the threshold level was selected for fixed water use. The severities and durations for drought events were then calculated at the selected threshold level. The streamflow duration curve was then developed. Drought events were obtained by using the streamflow and threshold level. Dry regions such as Namibia are more likely to experience droughts that last for several years (Sung & Chung, 2014), therefore the annual time step of streamflow data was used.

2.2.3.3.2. Construction of the flow duration curve
A flow duration curve (FDC) is used to characterize the flow regime of a stream. It is a graphical illustration that shows the relationship between any given discharge and the percentage of time that discharge is equalled or exceeded. The FDC was constructed using monthly streamflow data from the period 1970 to 2016. The streamflow data was first rearranged in descending order (maximum to minimum). The probability exceedance F(x) was calculated as follows:

$$1-F(x) = 100 * [i/(N+1)]$$

1-F(x): the probability that a given flow will be equaled or exceeded (% of time).
i: the ranked position on the listing.
N: the length of the sample.
Each ordered observation was then plotted against *its* corresponding duration or exceedance probability to produce the FDC.

2.2.3.3.3. Standardized Precipitation Index (SPI)
The SPI is used to determine precipitation deficit or excess. It is the cumulative probability of a rainfall event occurring at a particular station. The rainfall data is fitted to a gamma distribution to allow the rainfall distribution to be represented by a probability function. Positive SPI values indicate precipitation values greater than the median precipitation and negative SPI values indicate precipitation values that are less than the median precipitation. A drought is said to begin when a continuously negative SPI reaches a value of -1 and below and is said to end when the SPI value becomes positive (McKee et al., 1993) (Table 2)

Table 2. Drought categories from SPI (Source: McKee et al, 1993)

SPI	Drought Category
0 to -0.99	Mild drought
-1.00 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
-2.00 or less	Extreme drought

Monthly precipitation data was the only input data for calculating the SPI. One meteorological station (Okahandja) in the vicinity of the Von Bach Dam for which long term precipitation data was available was selected for calculating the SPI. Other stations were omitted because of their proximity to the dam as well as due to missing data.

Table 3 Okahandja Meteorological Station

Station	Latitude	Longitude	Elevation (m)	Period
Okahandja	-21.9667	16.91667	1 337	1975-2017

The SPI values were calculated using the 6 months' time scale and the average SPI for the wet season (October to March) were derived and plotted.

2.2.3.4. Activities and Engagement

Preliminary results were presented in Windhoek at FRACTAL's second learning lab.

(a) Field trip to Kombat area was conducted to collect borehole data supplying water to Windhoek area.
(b) WEAP online training course attended by researchers and research assistant.
(c) All data collected and analyzed for objective A.
(d) Write up of article (in progress) for academic journal.
(e) Stakeholder meeting held, where final results were presented.

2.3 Livelihoods

2.3.1 Study Design and Sampling

The study used a quantitative cross-sectional design. A two-stage cluster sample was selected, such that at the first stage a random sample of 35 census blocks with probability proportional to size, and thereafter, at the second stage in each census block a fixed number of households were selected from 35 census blocks. The head of household was interviewed in each selected household.

2.3.2 Survey Instrument

A questionnaire was developed to measure indicators of water security, livelihood and well-being. The development of metrics involved multi-stakeholder inputs as support for decision-making, but also offered opportunities for integrating ecosystems to livelihoods. Two definitions guided the construction of the metrics on water security:

(a) The reliable availability of an acceptable quantity and quality of water for production, livelihoods and health, coupled with an acceptable level of risk to society of unpredictable water-related impacts (D. Grey and C.W. Sadoff, 2007).
(b) The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socioeconomic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (UN University, 2013)

2.3.3 Data Analysis

Descriptive summaries of key indicators, exploratory spatial analysis and regression analysis were used to examine linkages between water security and livelihoods. Based on factor analysis, a total of two multi-dimensional, composite, and multi-attribute indexes on water security were generated. These include Household Water Security and Economic water security on water security. Household water security is the foundation and cornerstone of water security. It is defined as providing all people with reliable, safe water and sanitation services. Household water security is an essential foundation for efforts to eradicate poverty and support economic development. Economic water security measures the productive use of water to sustain economic growth in the food production, industry, and energy sectors of the economy.

2.3.4. Activities and engagements

In implementing this component, the project team has engaged with key stakeholders. A key-informant tool was developed to solicit clear understanding of what are key elements of water security, livelihoods and how these are impacted by rapid urbanization and climate change. The process included identifying:

(a) which indicators should be included and at what scale,
(b) how to measure them,
(c) how they feedback on each other and affect established institutions such as law and regulation,
(d) how actionable they are, and
(e) how well they represent the dynamic, non-stationary, and complex systems they seek to represent.

Outputs from the project were subsequently shared with stakeholders, in a series of workshops. These were three in nature:

(a) from City of Windhoek: water experts, climatologists, and city planners;
(b) City learning lab participants, mostly drawn from FRACTAL partner cities such as City of Lusaka, and the City of Windhoek;
(c) Conference presentation on EcoSystem Services

3.0 Outcomes and Outputs

3.1 Governance

3.1.1 UJAMS Case study

(a) Governance of UJAMS Water Reclamation Plant

Results from questionnaire survey and literature review of the story of the UJAMS (Figure 2) are summarized in Table 4 following the concept of urban governance configuration proposed by Scott (2017)

Figure 2. UJAMS Waste Water Treatment Plant. Windhoek.

Table 4 Urban governance configuration for UJAMS Waste Water Treatment Plant that led to establishment and operation of the plant

	Element	Content
1	Discourses	Water is viewed as a scare resource by the water users especially the water-dependent industries. On the other hand, it is an important but scarce commodity by NAMWATER, the bulk supplier that sale water to the City of Windhoek and the City of Windhoek who distributes and sells the water to city residents and other users such as the Industry. Since water is in short supply due to drought and variability in rainfall, the city views reclamation of water as an important "unconventional source of water" that can alleviate demand for water for multiple-use. The other discourse is regarding reduction of pollution of the environmental from Industrial effluent. Climate change vulnerability adversely affects water supply to the city. This is an important emerging issue of discussion amongst various stakeholders as articulated on the basis of the National Climate Change Policy and Climate Change Strategy and Action Plan. Lastly but not least, the most recent drought of 2013-2017 has led to more concerted efforts and cooperation amongst key stakeholders i.e. City of Windhoek, NAMWATER, Ministry of Agriculture Water and Forestry (MAWF)
2.	The actors	The following are the main actors that play(ed) important role in the establishment of the UJAMS water treatment plant. **(a) State:-** a. Ministry of Agriculture, Water and Forestry: (MAWF) Regulating Role. (b) **Non-State**:- a. City of Windhoek (CoW) • Administrative actors (Bureaucracy) (No decision-making authority) • Strategic Executive Forum (make recommendations) • CEO and Departmental Strategic Executives • Department of Infrastructure Water Technical Services • Political actors o Management Committee & Full Council (takes decisions) b. Industrial effluent suppliers: Industries such as Brewery, Abattoir, Beverage, Tannery c. International: WABAG, Veolia, CIM (Owners) a. Other: consultants (e.g. Africon), researchers (e.g. Zeri Project)

3	Legislation, Policies and Mandates	Establishment and operation of the UJAMS Waste Water Treatment Plant fulfills the following:- (a) **Water & Environmental Policies** a. National Water Policy White Paper 2000 b. Water Supply and Sanitation Policy 2008 c. Water Resources Management Act 24 of 2013 d. Environmental Management Act of 2004 (b) **Mandates of:** a. Bulk Water Master Plan b. Sewer Master Plan c. WRM: Water Demand Management & Aquifer management d. WRM: Bulk water supply & wastewater treatment e. WRM Pollution control f. WRM: Water Quality monitoring g. WRM: Wastewater treatment effluent monitoring h. WRM: Industrial Pollution monitoring **(c) Climate Change Policy** a. The Climate Change Policy, Strategy and Action Plan enacted in 2011.
4	Materialities	For the UJAMS materialities include the following:- (a) Source (and infrastructure) of water to Industries • NamWater's 3 dam system. Bulk water transported via pipes to Windhoek • Water distributed by City of Windhoek via pipes to Industries (and other water users) such as Brewery, Abattoir, Beverage, Tannery (b) Effluent from Industries • Initially drained into the environment (nearby river beds / channels) • Oxidation ponds developed • Establishment and operation of the UJAMS Waste Water Treatment Plant (c) Technologies • Biological digestion: Oxidation ponds • UJAM treatment plant: **ISO:** IS09001, 2008 certified **and** fully automated. **Processes:** Fine screening, Grit removal, Dry weather buffer tank, Fine Sieving, Membrane Filtration, UV-Disinfection, Clear water tank and Sludge treatment.

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Decision-making processes</td><td>

Water-dependent industries established and operated in City of Windhoek
Effluent initially discharged in the environment leading to pollution of areas where these were disposed [Pollution problem created]
CoW established and operated oxidation ponds to address the pollution and odour problem.
Oxidation ponds were repositories for the oxidative processing of industrial effluent.
Processing ponds gradually became overloaded and unable to handle the load, resulting in inadequate treated effluent discharged into the Klein Windhoek River and the pollution load reaching Swakoppoort Dam.[Further pollution problem] HENCE need for a better and more efficient system
Drought exerted more problems on water security. This was compounded by high urbanization leading to high demand of water putting. HENCE need for unconventional sources of water.
CoW in consultation with MAWF and other actors invited bids for alternative ways to treat industrial effluent to avoid pollution and also to reclaim waste water
WABAG: European manufacturer of water treatment technological equipment including drinking water treatment, industrial wastewater treatment, cleaning of swimming pool water and waste water treatment bade for this invitation for solution to these water related problems
WABAG was awarded the contract to design, build, own and operate this effluent treatment plant for the Ujams Industrial Park located in the north of the city of Windhoek
It caters for effluents emanating from industrial facilities namely; the Brewery, Abattoir, Beverage company, Chocolate producer, and a Tannery

In summary:

Process involved adherence to National Policies on Water and Environmental Management
City of Windhoek has independence of water distribution and accounting for the city.
Decision made by Council to engage in public private partnership.
Involvement of actors
Technical support and Funding support from international organization
</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

	Implementation of policies and outcomes,	**Output of the process**:- Establishment and operation of Ujams Windhoek Industrial Effluent Reclamation Plant

General information about UJAMS (UWWTP)

It is owned by a joint venture of Veolia (France), CIM (Austria) and WABAG (Germany), in a Build Own, Operate and Transfer (BOOT) contract with the City of Windhoek. It was piloted for a year (2010-2011) and was commissioned in 2014. UWWTP is situated in Northern Industrial Are and has a capacity of 5175 m^3/day. The UWT Company will operate and maintain the plant for 21 years. It has a team of 5 people (Process and Research, Maintenance and Electrical, Projects, Plant technician, Lab technician) since it is fully automated. UWWTP treats industrial wastewater only from Northern and Lafrenz Industrial Areas by gravity. Treated discharge these into the Kleine Windhoek River. As part of the effort to alleviate water demands and provide alternative or additional water for reuse, some of the effluent is used for for irrigation & industry reuse such as road construction, paving etc.

(b) Efficacy of the UJAMS Water Reclamation

In this section, we plot results of concentrations of total potassium and nitrogen (TKN), total suspended solids (TSS), chemical oxygen demand (COD), orthophosphate and conductivity

It is evident from Figure 3 that UJAMS significantly reduced that amount of TKN from the raw effluent compared to when these were discharged in the oxidation ponds.

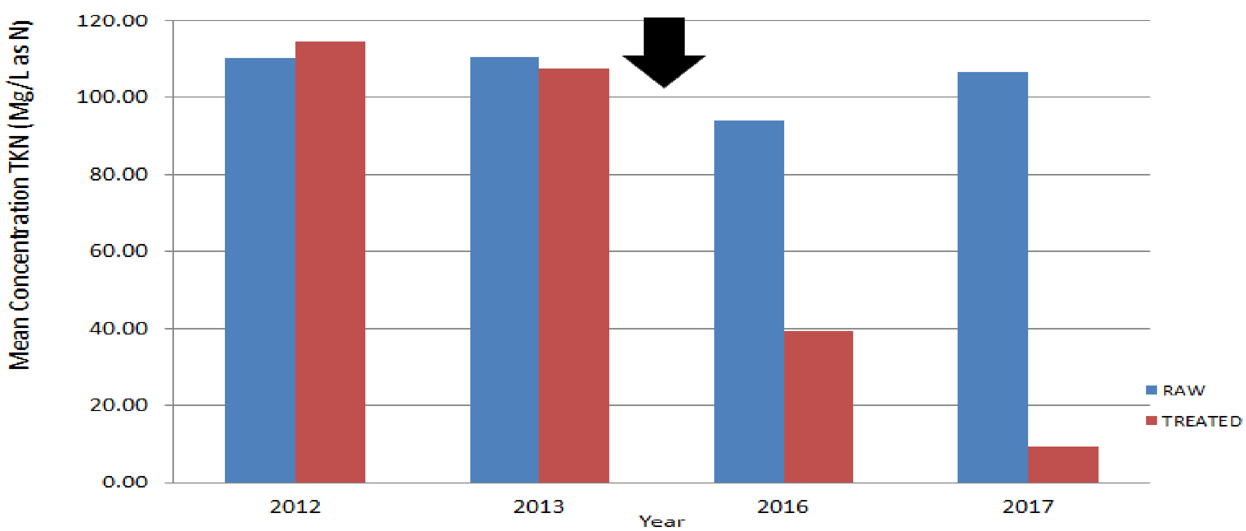


Figure 3. Mean concentrations of Total Potassium and Nitrogen [TKN] (mg/L as N) for effluent discharged from industries before (raw) and after treatment at the UJAMS Water reclamation plant. UJAMS was constructed between 2014 and 2015. Black arrow separates effluent received and treatment in oxidation ponds (2012-2013) and following operation of UJAMS (2016-2017)

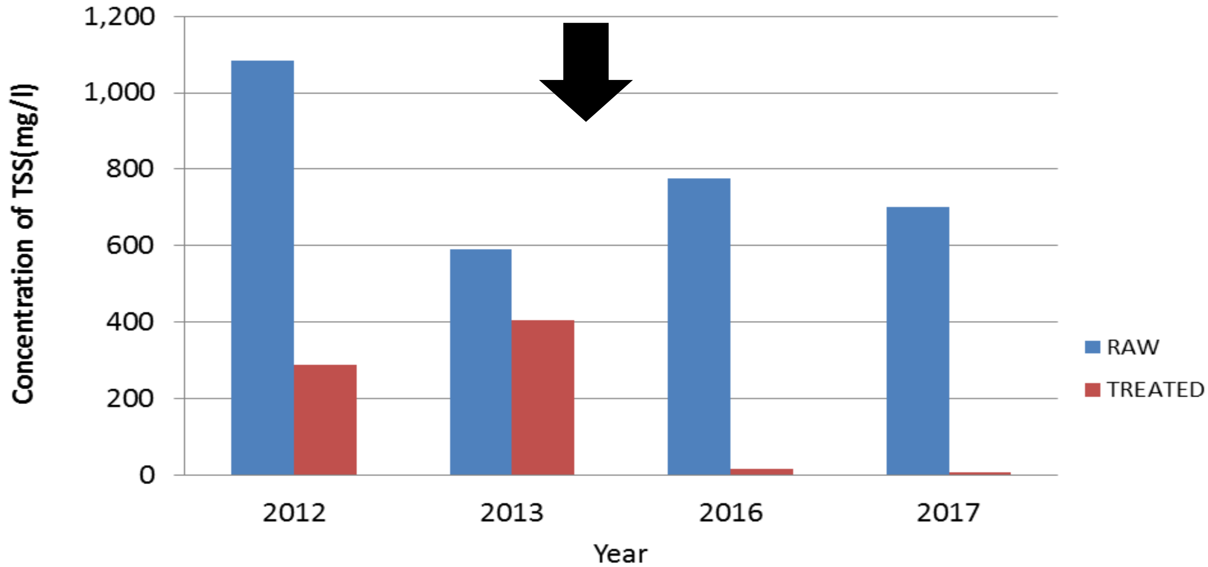


Figure 4. Mean concentrations of Total Suspended Solids [TSS] (mg/L as N) for effluent discharged from industries before (raw) and after treatment at the UJAMS Water reclamation plant. UJAMS was constructed between 2014 and 2015. Black arrow separates effluent received and treatment in oxidation ponds (2012-2013) and following operation of UJAMS (2016-2017)

The UJAMS treatment plant significantly removed TSS from the raw effluent than when these were discharged in the oxidation ponds (Figure 4)

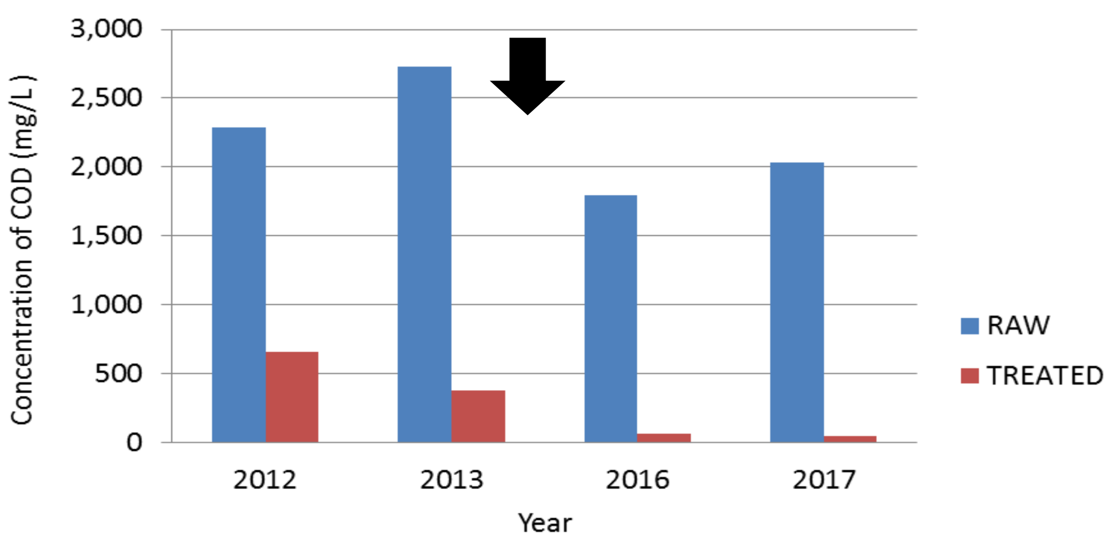


Figure 5. Mean Chemical Oxygen Demand [COD] (mg/L) for effluent discharged from industries before (raw) and after treatment at the UJAMS Water reclamation plant. UJAMS was constructed between 2014 and 2015. Black arrow separates effluent received and treatment in oxidation ponds (2012-2013) and following operation of UJAMS (2016-2017)

Figure 5 reveals that the treatment plant at UJAMS significantly reduced COD from the raw effluent compared to the time when these were discharged and treated biologically at the oxidation ponds.

Concentrations of Orthophosphate are significantly removed from the industrial effluent at the UJAMS water reclamation plant compared to when oxidation ponds were used (Figure 6)

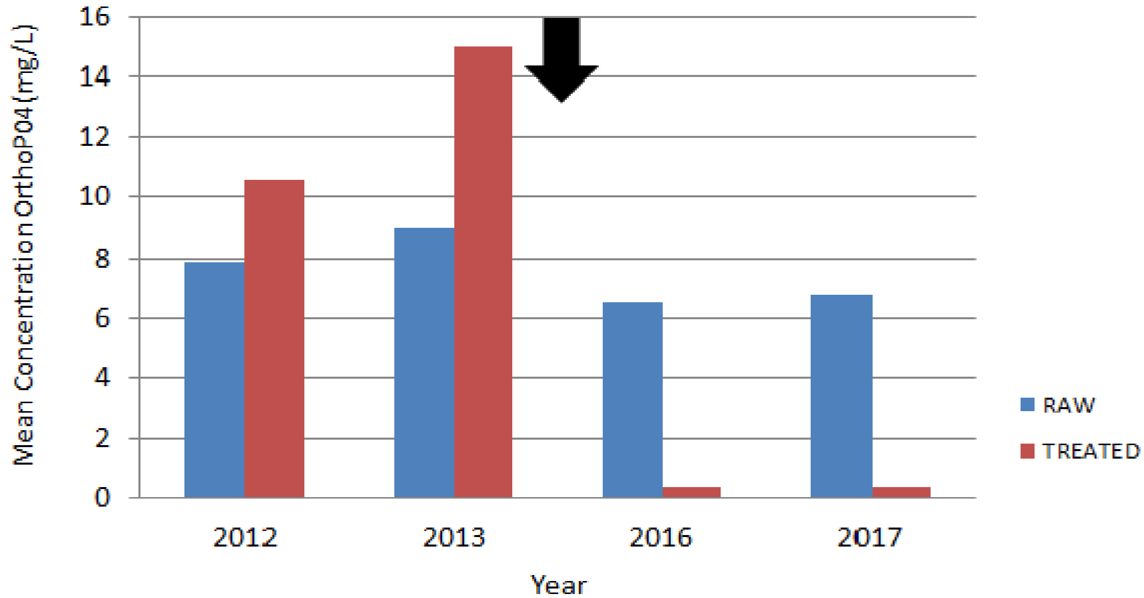


Figure 6. Mean Orthophosphate concentrations (mg/L) for effluent discharged from industries before (raw) and after treatment at the UJAMS Water reclamation plant. UJAMS was constructed between 2014 and 2015. Black arrow separates effluent received and treatment in oxidation ponds (2012-2013) and following operation of UJAMS (2016-2017)

The analysis revealed that conductivity of the effluent did not vary significantly between the raw and treated effluent in the oxidation ponds as well as after it was discharged through the UJAMS reclamation plant (Figure 7).

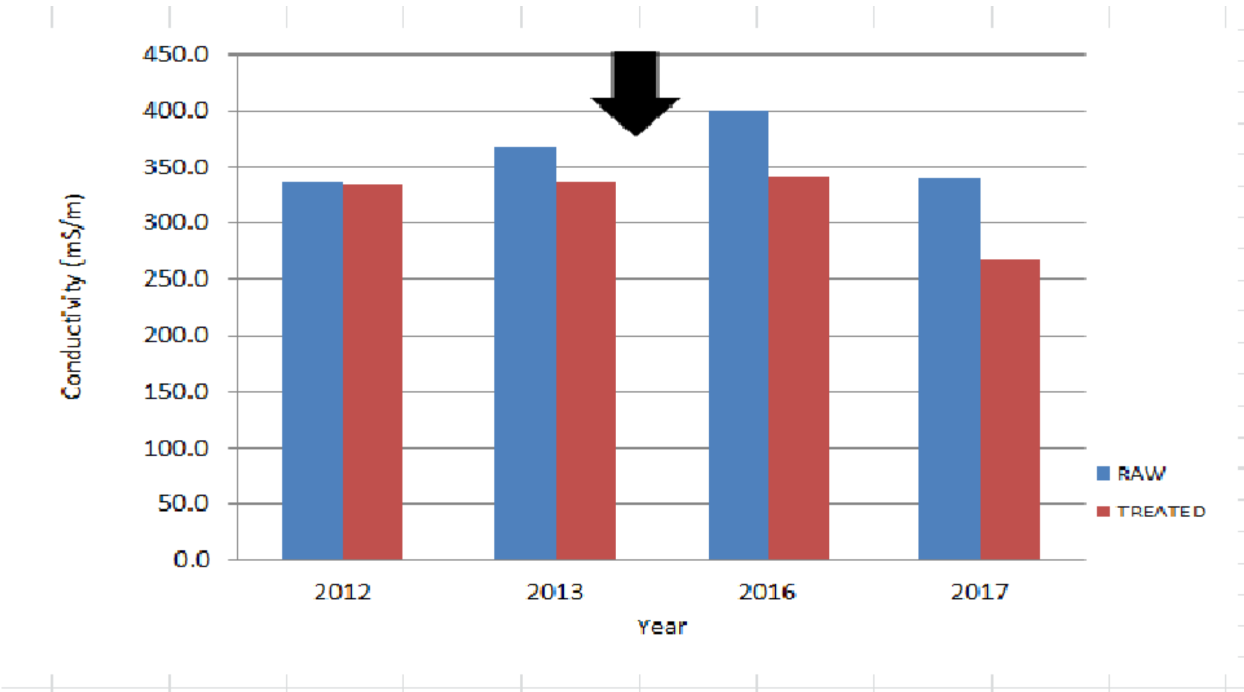


Figure 7. Mean Conductivity (mg/L) for effluent discharged from industries before (raw) and after treatment at the UJAMS Water reclamation plant. UJAMS was constructed between 2014 and 2015. Black arrow separates effluent received and treatment in oxidation ponds (2012-2013) and following operation of UJAMS (2016-2017)

3.1.2 Policy analysis

Analysis of Water Management Plan for City of Windhoek 2017 and Transformational Strategic Plan (2017-2022) for City of Windhoek policies revealed that despite being developed recently after the Namibia Climate Change Policy, Strategy and Action Plan had been enacted, very little climate change related issues are presented and used in these policies despite Windhoek suffering from impacts of climate change especially as it related to water quality and quality. In the Water Management Plan for City of Windhoek 2017 for examples, the following key climate change words are not used at all:- climate, adaptation, resilience, vulnerability, dry spell, flood, disaster just to mention a few. Similarly, the following key climate change concepts or words are also missing or not mentioned in the Transformational Strategic Plan (2017-2022):- IPCC, dry spell, sea level, precipitation, uncertainty, scenario. However, words such as water, energy drought, adapt, resilient, climate, drought, vulnerable appear in the polies where these are used in climate change related issues.

This analysis through not exhaustively done for all the Cow polices that are related to water, reveals that despite a lot that many actors and engaged regarding water sourcing, transportation and distribution, there is very little deliberate consideration of Climate Change issues and this is true for UJAMS establishment and operation. It is very clear therefore that the focus of FRACTAL on climate change information and how to mainstream this in city planning and development in the city of Windhoek is very relevant and needs much effort and attention.

3.1.3 Capacity Building

Mr Gerhard Iiputa, a technologists in the department of Biological Sciences, has been enrolled as a MSc student at the University of Namibia. He will undertake a research project entitled:- “Assessment of the potential uptake of chromium and its effects on growth and development of selected plant species exposed to industrial effluent from Ujams industrial waste water treatment plant in Namibia”. The study will generate valuable information that will be useful to assess the level of pollution through chromium which is discharged from one of the industries. It will also serve to identify plants that are useful or serve in phytoremediation. The research proposal of the student has been approved, sampling sites have been identified. He will be supervised by Prof J.K. Mfune and Dr Ezekiel Kwembeya both from the department of Biological Sciences.

3.2 Water demand and supply

3.2.1. Results

Water demand of Windhoek

Figure 7 shows that, water demand in Windhoek is increasing at fast rate. In 2003, 2004, 2005 and 2006 the water demand was below $8Mm^3/a$. However, from 2007 onward the water demand increased to about $25Mm^3$. The increase could be mainly due to human population and industrials and construction activities.

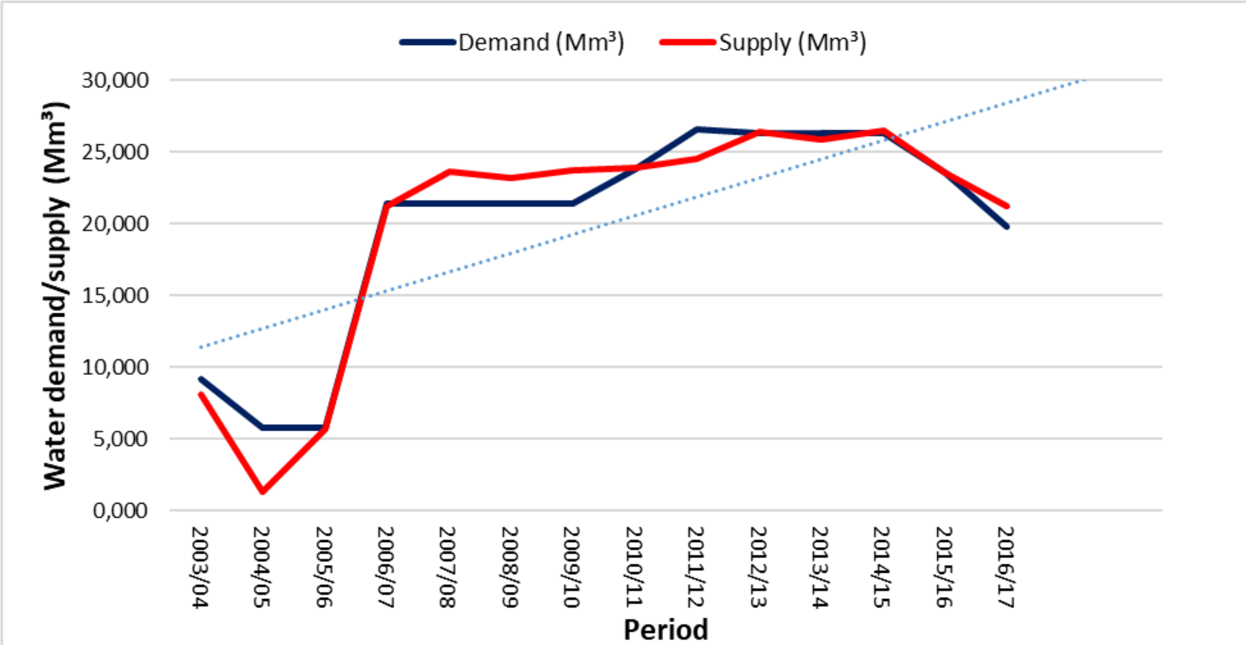


Figure 7: Water demand and supply of Windhoek

Streamflow drought events

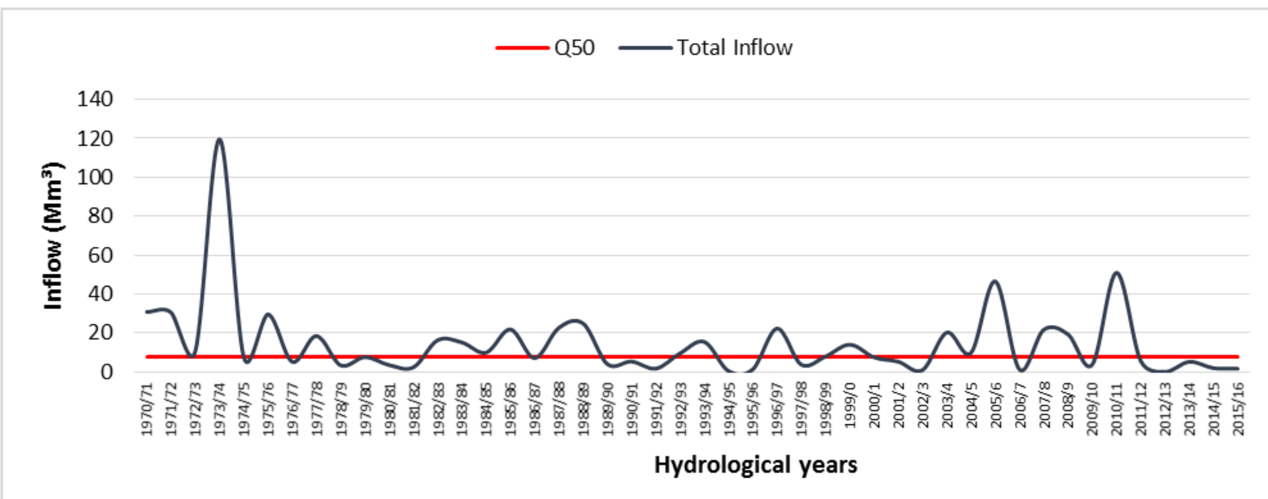


Figure 8. Streamflow drought events for inflow into Von Bach Dam

The threshold of Q_{50} was chosen because the mean, which is generally most commonly selected for ephemeral rivers was found to high and may not necessarily be representative. Drought events considered were thus those that were below this threshold. Based on selected threshold level of Q_{50}, drought events were observed between 1978 to 1982 and then followed by a wet period from 1983 to 1989/90. This was then followed by another drought period from 1989/90 to 1991/92. The next drought was observed between 1994/95 to 1995/96 and then another drought in 1997/98. Droughts also occurred in the years 2002/03, 2006/07, 2009/10. Drought periods were not necessarily continuous and a wet period was always followed by a drought event. The droughts with the longest duration were observed from 1978/79 to 1981/82 and between 2011/2012 to 2015/16 with an annual streamflow of less than 7.8 Mm^3 for a period of 4 years. Based on the selected threshold of 7.6Mm^3, droughts with the highest intensities were observed in 1994/95, 2002/03 and 2012/2013 with a deficit of -7.21Mm^3, -6.65Mm^3 and -7.6Mm^3 respectively, making the 1994/1995 drought one of the most intense droughts over the recorded period. The average flow in 1995 was only 0.0325 Mm^3 with 75% and 83.3% of zero flows observed respectively. The worst drought for the study period therefore occurred in 2012/13 with a total annual flow of zero. A study by Woo & Tarhule (1994) tested seven thresholds, *Q*5, *Q*7.5, *Q*10, *Q*12.5, *Q*15, *Q*17.5, *Q*20, for ephemeral rivers in Nigeria and argued that these are realistic levels due to the large proportion of zero flow (several months every year). Droughts are a natural part of Namibia's climate, therefore zero flows for ephemeral rivers are very common. Ephemeral rivers such as the Swakop River is dry most of the year and only flows during periods of heavy rainfall.

Flow Duration Curve (FDC)

A flow duration curve is used to determine the percentage of time that a certain amount of flow in a river is equaled or exceeded (Croker et al., 2009). This shows the flow regime and is derived from gauged river data. A flow duration curve for the annual streamflow of the Swakop from 1970-2017 was constructed and the results are presented in Figure 4.

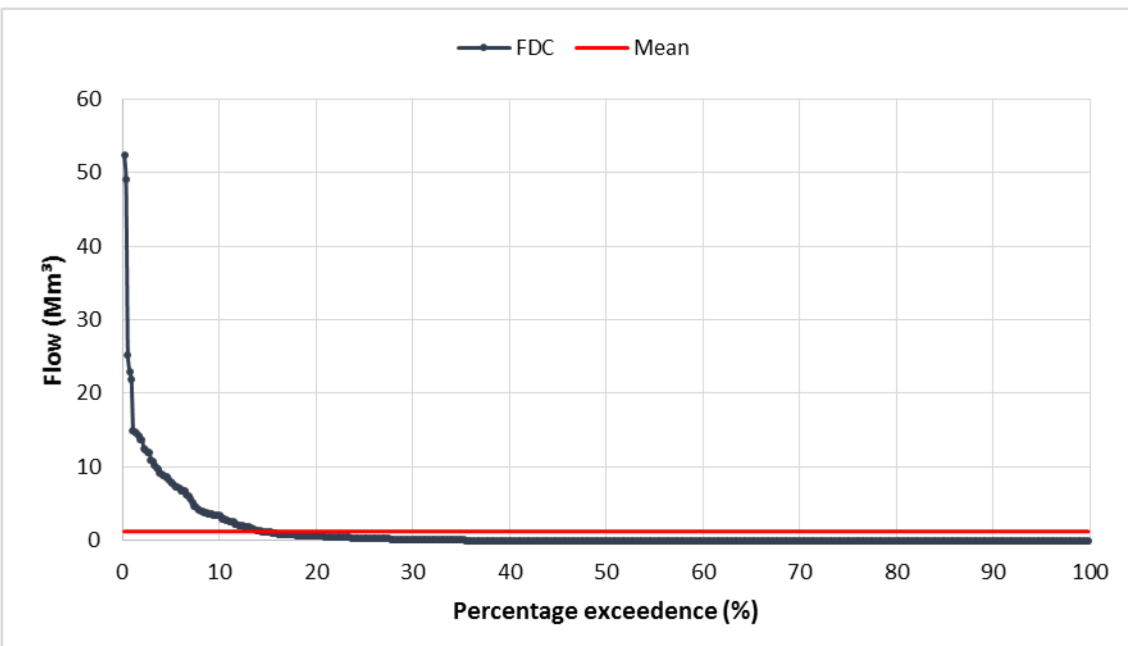


Figure 9. Flow duration curve for the Swakop river from 1970-2017.

The results are indicative of a noticeably ephemeral river with a high probability of extremely low to zero flows. It was found that only 14.3% of the monthly flows exceeded the mean of 1.2Mm^3 for the recorded period. The median and mode were all zero for the period. This is not unusual because of the nature of the river. It also highlights how using the mean as a measure of central tendency can be misleading and not necessarily represent the streamflow that often has highly skewed data. The monthly streamflow data for the Swakop river indicate that the river runs dry for most months in a year where some years were observed with more zero flows than others. The years 1994/1995 and 2002/2003 had the most zero flows.

Standardized Precipitation Index (SPI)

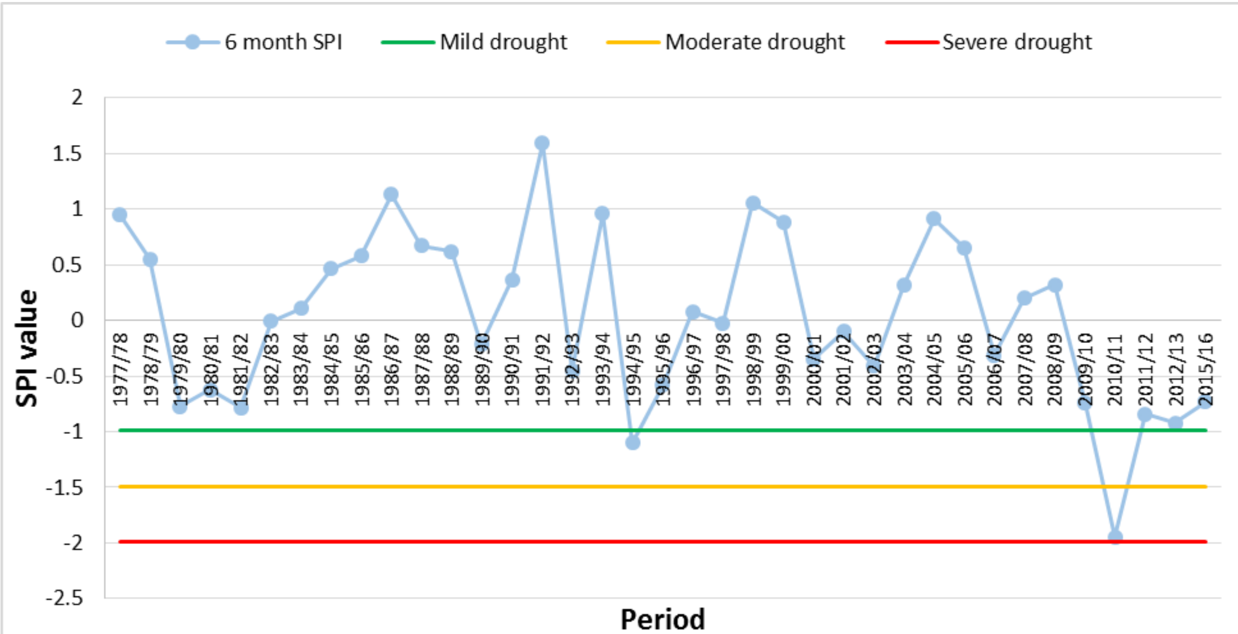


Figure 10. SPI values for the Okahandja station for the period 1977 – 2016

Figure 10 depicts the 6-month SPI for the Okahandja rainfall station. The graph shows that the area has experienced several periods with mild droughts (SPI: 0 to -.0.99) and these were observed in 1979/80 to 1981/82, 1989/90, 1995/96, 2000/01 to 2002/03, 2006/07, 2009/10 and 2011/12 to 2015/16. The area also experienced a moderate drought (SPI: -1.00 to -1.49) during one period 1994/95. The results also indicate that only one severe drought was experienced during the selected study period which was observed in the period 2010/11. The droughts between 1979/80 to 1981/82, 2000/01 to 2002/3 had the longest durations, extending over 3 years. The drought events are related to the rainfall figures recorded during the rainy season of October to March. Because Namibia is mostly dry between April to September, the rainfall figures for these months were not considered because they would be zero for most years.

3.3 Livelihoods

3.3.1 Results

3.3.1.1. Geographical distribution of data

Table 5 shows the distribution of sampled households. The majority of participating households were from Katutura area. Figure 1 presents the geographical distribution of households across census blocks. Close to two-thirds of the households were from informal settlements.

Table 5: Distribution of households in the sample

Constituency	Frequency	Percent
John Pandeni	34	3.9
Katutura Central	44	5.1
Katutura East	44	5.1
Khomasdal	131	15.2
Moses Garoeb	185	21.4
Samora Machel	131	15.2
Tobias Hainyeko	165	19.1
Windhoek Rural	89	10.3
Windhoek West	26	3.0
Missing	14	1.6
Total	863	100

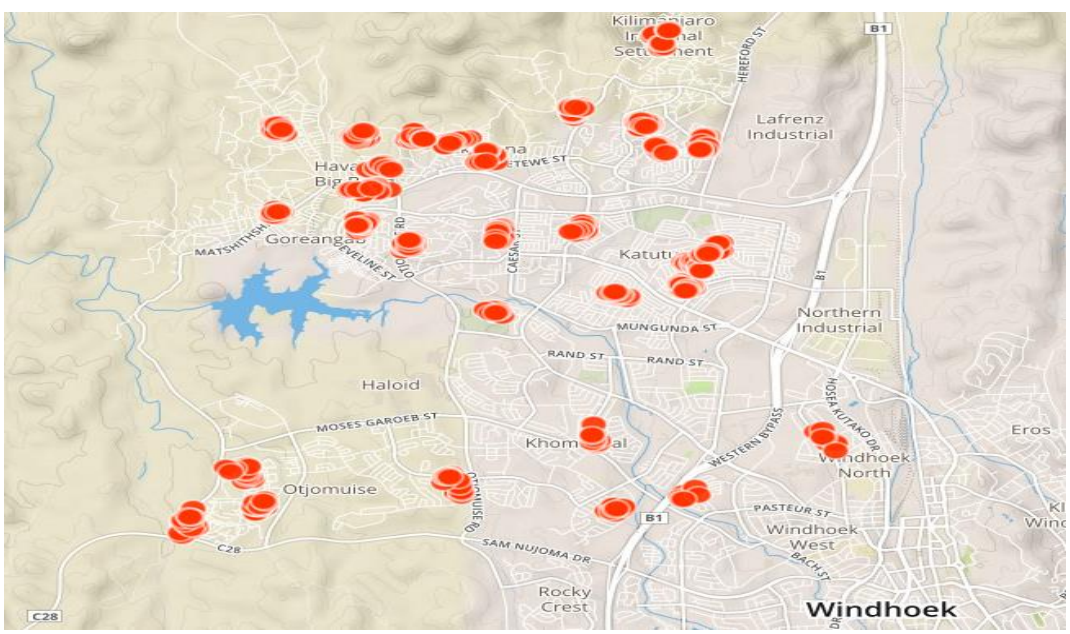


Figure 11: Geographical distribution of sampled households

The household characteristics of the sample are provided in Table 5. Close to 30% of the households were female centred, while 22.8% were male centred type of households. This was followed by those that were nuclear (20.2%) and extended type of households (17.8%). Table 6 gives details on the source of income. Formal wage work was the main source of income for close to half of the sampled households. Businesses- be it formal or informal were another important source of income (18.9%), followed by informal wage work (15.65). Other less common sources were cash remittances (7.6%), social grants (5.4%) and others including rentals and investments (0.9%).

Table 5: Household type from the sample

Household type	**Frequency**	**Percent**
Extended (Husband/male partner and wife/female partner and children and relatives)	154	17.8
Female centered (No husband/male partner in the household, may include relatives, children, friends)	233	27.0
Male centered (No wife/female partner in household, may include relatives, children, friends)	197	22.8
Nuclear (Husband/male partner and wife/female partner with or without children)	174	20.2
Single person household (respondent lives alone)	77	8.9
Others	30	3.2
Total	863	100

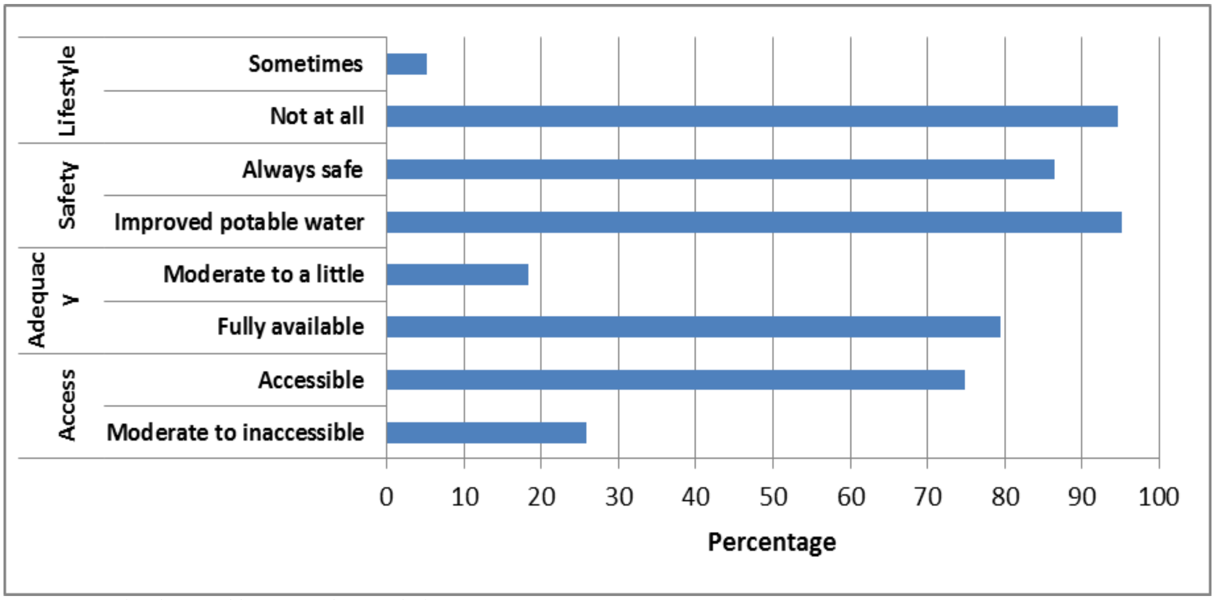
Table 6: Sources of income

Source	Frequency	Percent
Formal wage work	445	51.6
Informal wage work	135	15.6
Businesses(formal and informal)	162	18.9
Cash Remittances	66	7.6
Social Grants	47	5.4
Others (investments, rentals)	8	0.9
Total	863	100

3.3.1.2 Water security

Water security was measured based on: (a) access; (b) adequacy, (c) safety, and (d) lifestyle. Access was based on time to source and time of waiting to fetch, while adequacy measured using reduction in amount available for household activities, including going thirsty, reduced meals or reduced washing. Safety refers to the type of source and perceptions of having drunk dirty water.

Lifestyle water security refers to the opportunity costs of collecting water, for example forgoing business activities due to lack of water or missing school because one has to collect water. Figure 2 show percentage households presenting the various components of water security. There is evidence of water security in Windhoek, across all the four dimensions. With regards to accessibility, the majority (75%) of the sampled households had access to water at all times, most of these were within their community or piped to their homes, and that the water was fully adequate in most of the time (79.4%). The available water was said to be of good quality to 95.6% of the households. The availability of water meant that their lifestyles were not affected (94.7%).



Note: Categories do not add to 100% due to missing responses

Figure 12: Water security scenarios in Windhoek

Figure 13 shows the various sources of water by area of residence. There were differences between areas with regards to the source of water. Although in all communities, piped water into the yard or homes was common, there was a good percentage of community taps in poor neighbourhood of Tobias Hainyeko and Windhoek rural constituencies. In some communities, like Windhoek West, John Pandeni and Katura central were full models of potable water.

Accessibility with regards to time and distance to water source is shown in Figure 14. About 32% of the households had water within their homes (0 minutes), while 41.4% were within 1-5 minutes, just outside their homes. Other households (24.4%) accessed water within their communities, at a time of 15-30 minutes. Only 0.5% had water sources in another community than theirs, requiring access time of more than 30 minutes.

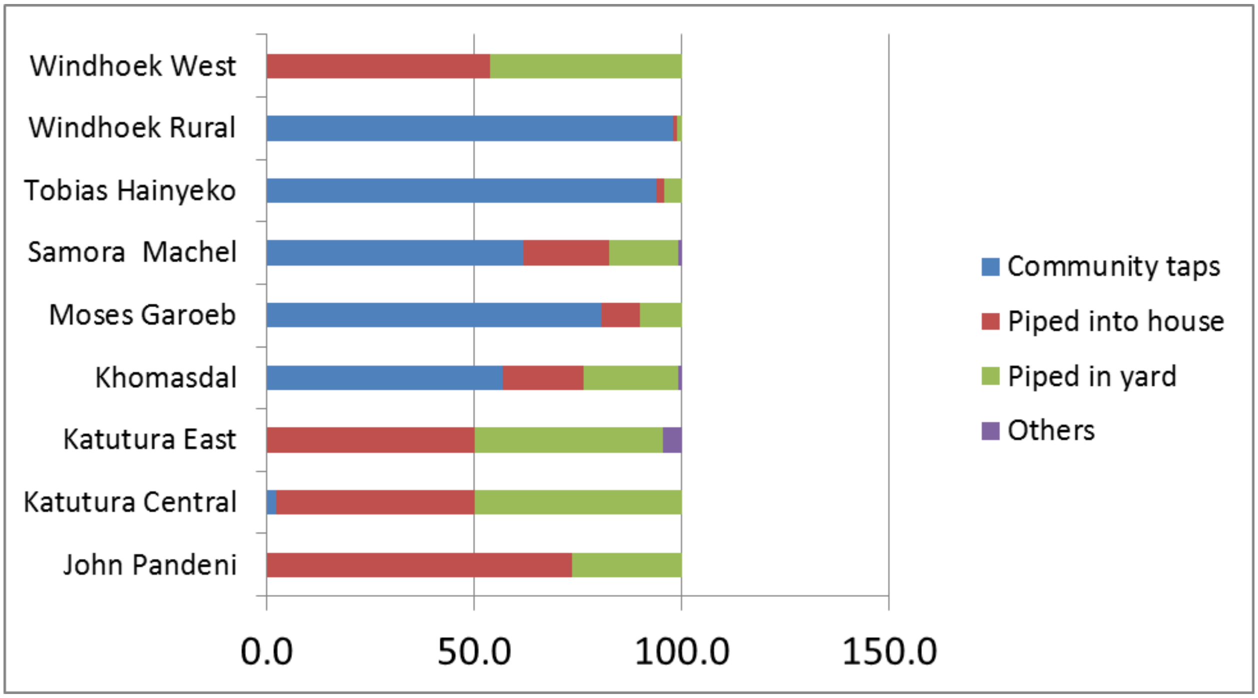


Figure 13: Sources of water by area of residence

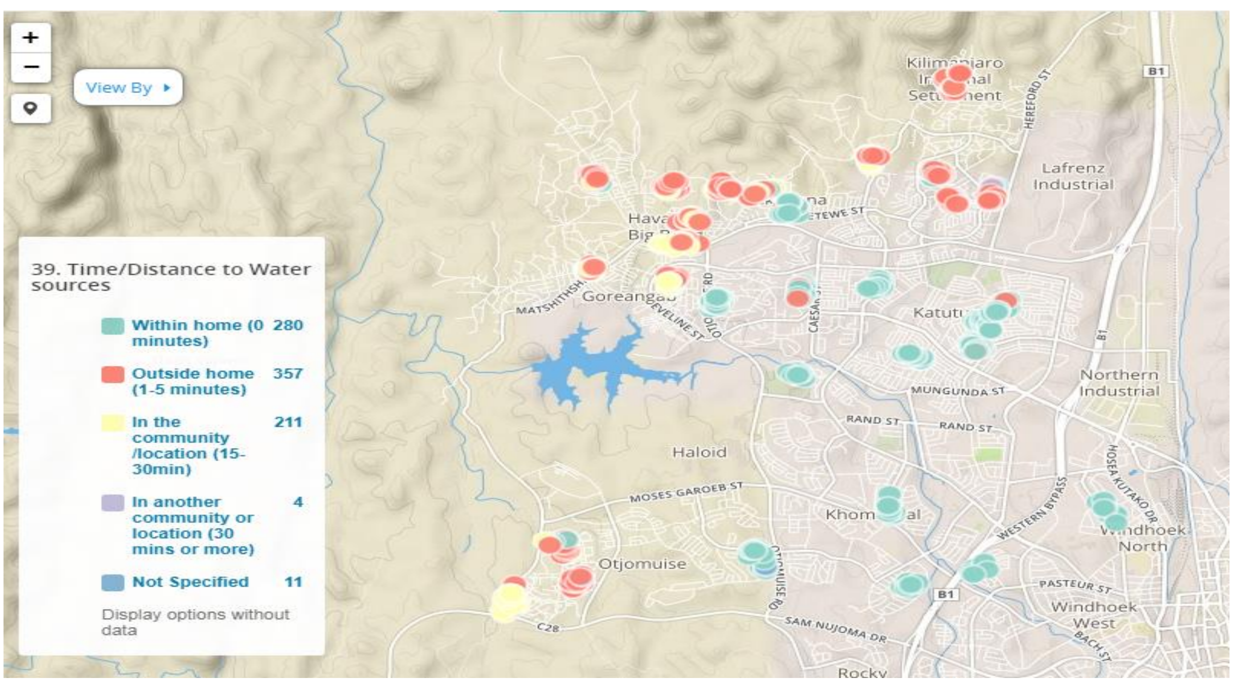


Figure 14: Accessibility of water sources in Windhoek

Despite water being accessible, some households did report incidences of water shortage. Figure 15 presents percentage distribution of households experiencing water shortage by area. Water shortage averaged between 27% in John Pandeni to 82% in Windhoek Rural, with an overall percentage for Windhoek estimated at 56%. Again, places where we have a lot of informal settlements –like Windhoek Rural, Moses Gaerob and Tobias Hainyeko experienced an above average water shortage.

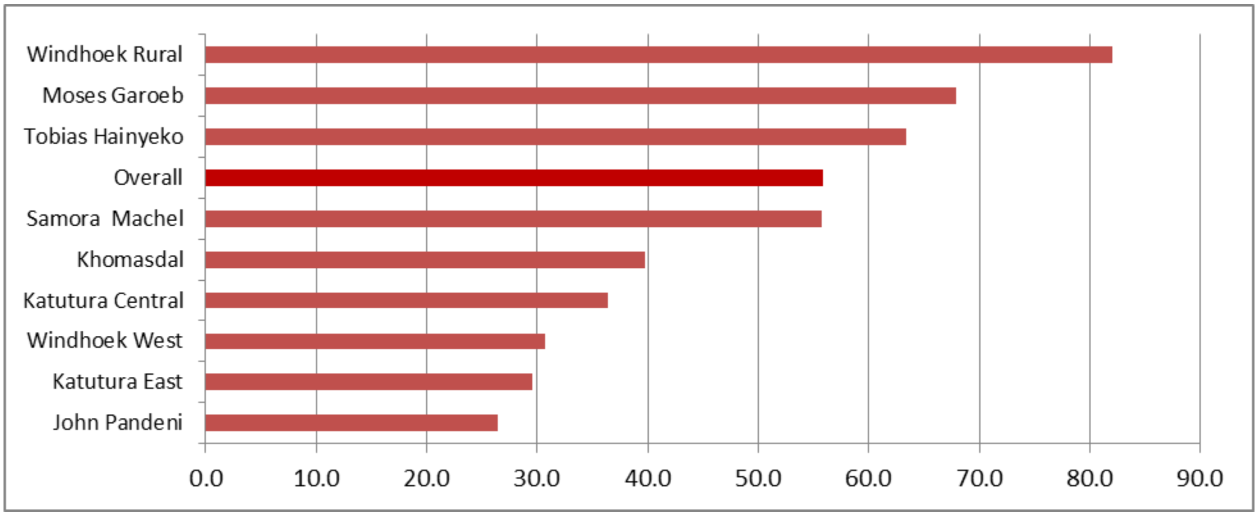


Figure 15: Experiences of Water Shortage

Water security challenges faced by the households included experiences of deteriorating water quality. This perception was measured in in comparison to the year preceding the survey date. Figure 16 shows a spatial distribution of experienced deteriorating water quality. The about two-thirds did not experience any changing water quality, while 32% indicated that there has been a notable change in water quality. The deteriorating water quality was experienced across the city. Other emerging issues on water in Windhoek are summarized in Figure 17. These include disposal of waste water, deteriorating water quality, water logging and rainfall flooding. These challenges were more reported in the poor neighbourhoods of Windhoek (like Tobias Hainyeko, Moses Garoeb,) and middle income areas of Khomasdal.

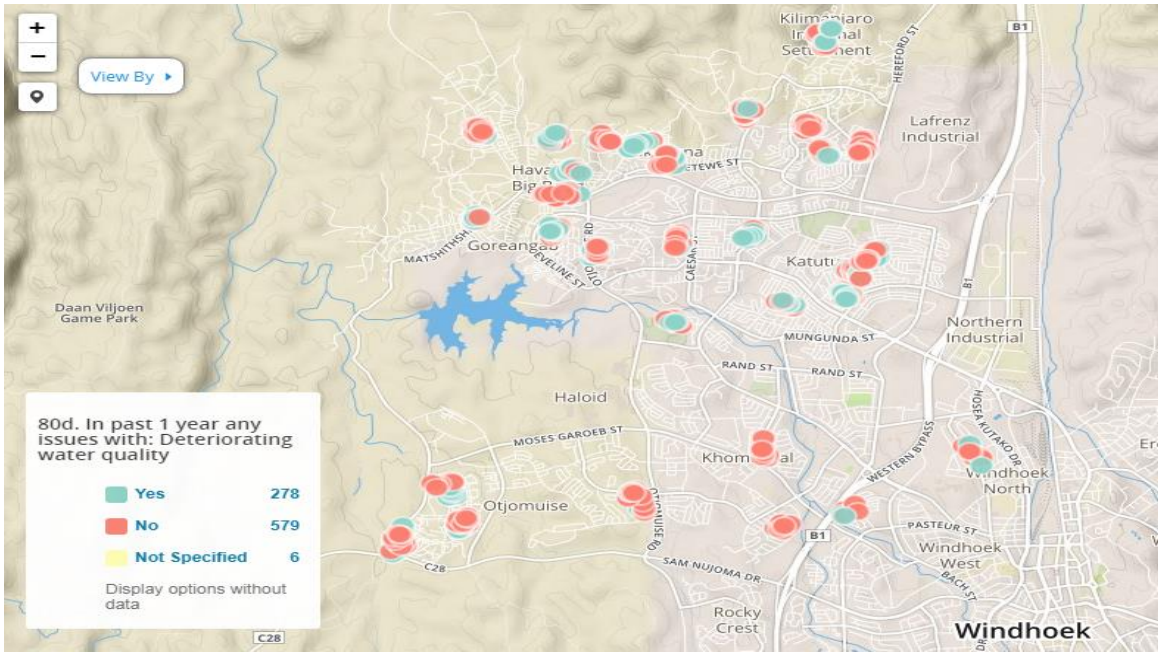


Figure 16: Spatial distribution of experienced deteriorating water quality in Windhoek.

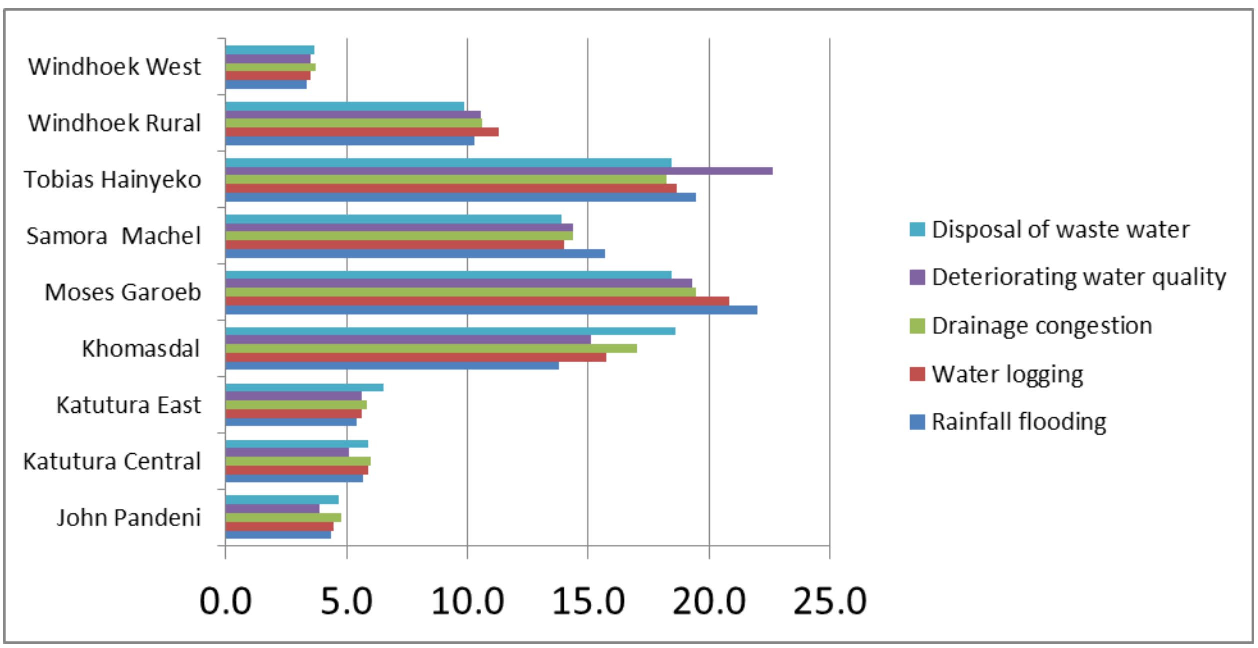


Figure 17: Emerging issues on water in Windhoek

3.3.2 Livelihood outcomes

In keeping with the objectives, the study further evaluated urban livelihoods, distinguishing between the overall livelihoods and those that are related to water. Figure 18 presents a summary of the main livelihoods. Three categories of livelihoods emerged: retailing, production and services. For retailing we identified the following activities: clothing, home-made meals, agri-products, groceries, snacks and drinks. In the production domain we observed: garments, crafts, food. The services domain has activities such as: repairing appliances, agents, personal care and car maintenance. From the figure, water related livelihoods were mostly in all domains. For retailing, water-related livelihood activities included home-made meals (8.5%), snacks and drinks (22.1%), whereas in production was observed in food (21.6%) and to a small extent in garments and crafts. Services related activities included agency (15.5%) and personal care (8.2%).

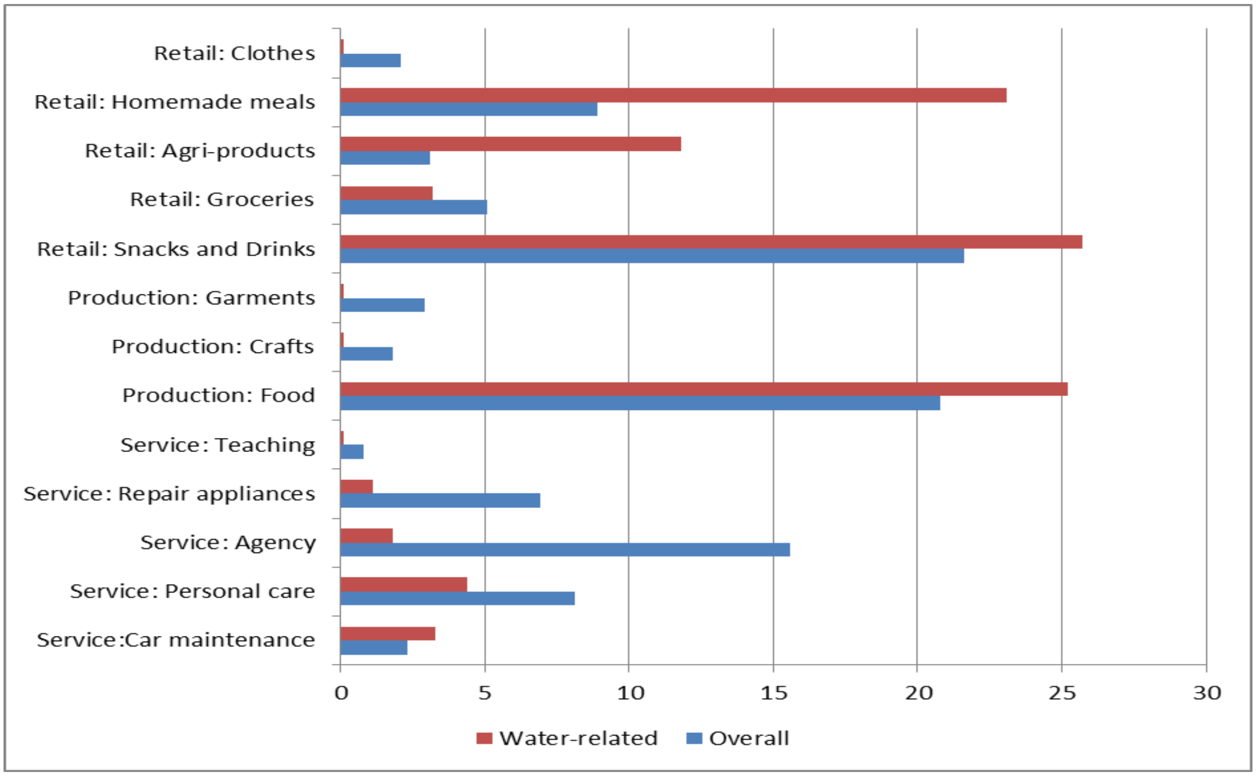


Figure 18: Urban livelihoods in Windhoek.

3.3.2.1 Defining Water Security for Sustainable Livelihoods

Our objective was to examine the linkages between water and livelihoods. We used the multiple indicator – multiple cause approach to link the synergies between water security (accessibility, adequacy, safety and lifestyle) to livelihoods. We exploited the aspect of provisioning ecosystem services for water to link the two- stressing the fact that a functioning water ecosystem should offer provisioning services that sustain urban livelihoods. In reciprocate, this entails rapid urbanization and climate change are potential threats to achieving stable provisioning services of water ecosystem. The outcomes of such an analysis were two measures/indicators: household water security – the capacity of meet household needs including drinking, food production, sanitation and hygiene; and economic water security- the capacity to sustain economic activities that depend on water. Figures 19 and 20 present a summary of the two measures.

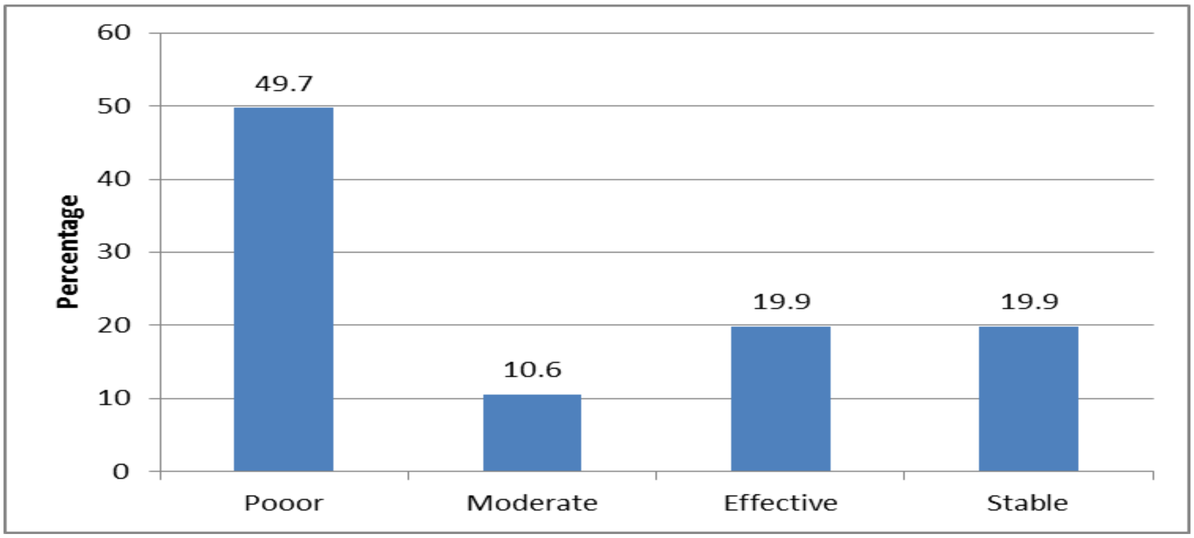


Figure 19: Household water security in Windhoek

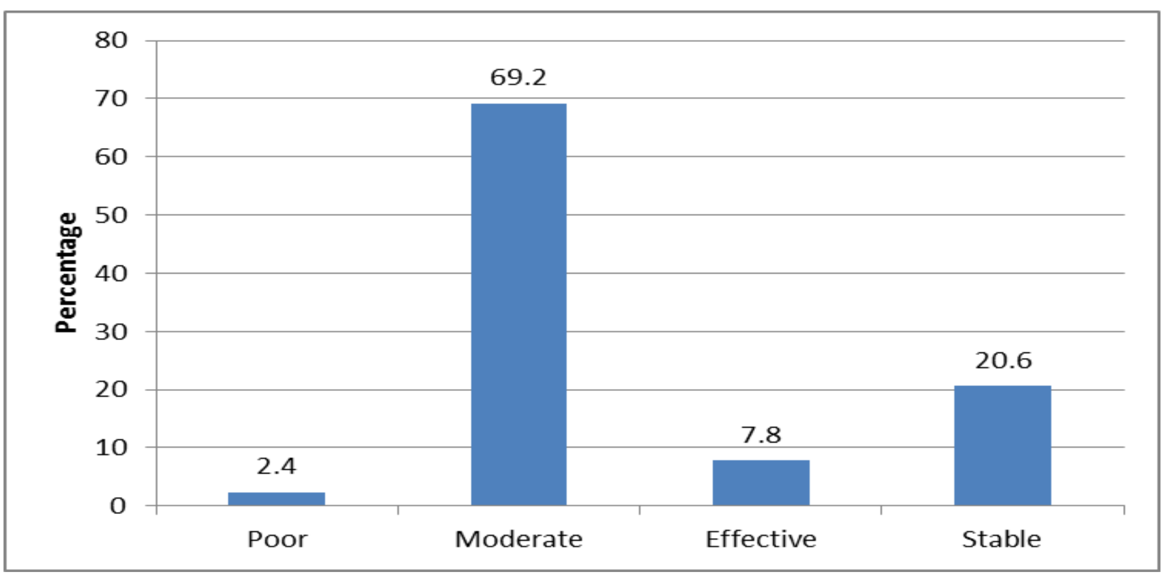


Figure 20: Economic water security in Windhoek

With regards to sustaining household water security, the analysis reveal that many areas have poor outlook (about 50%), while cumulative 40% have a stable outlook. A further analysis shows that household water security was negatively correlated with well-being ($r=-0.75, p=0.02$), indicating higher levels of household water insecurity was related to deteriorating well-being. Figure 11 shows the results.

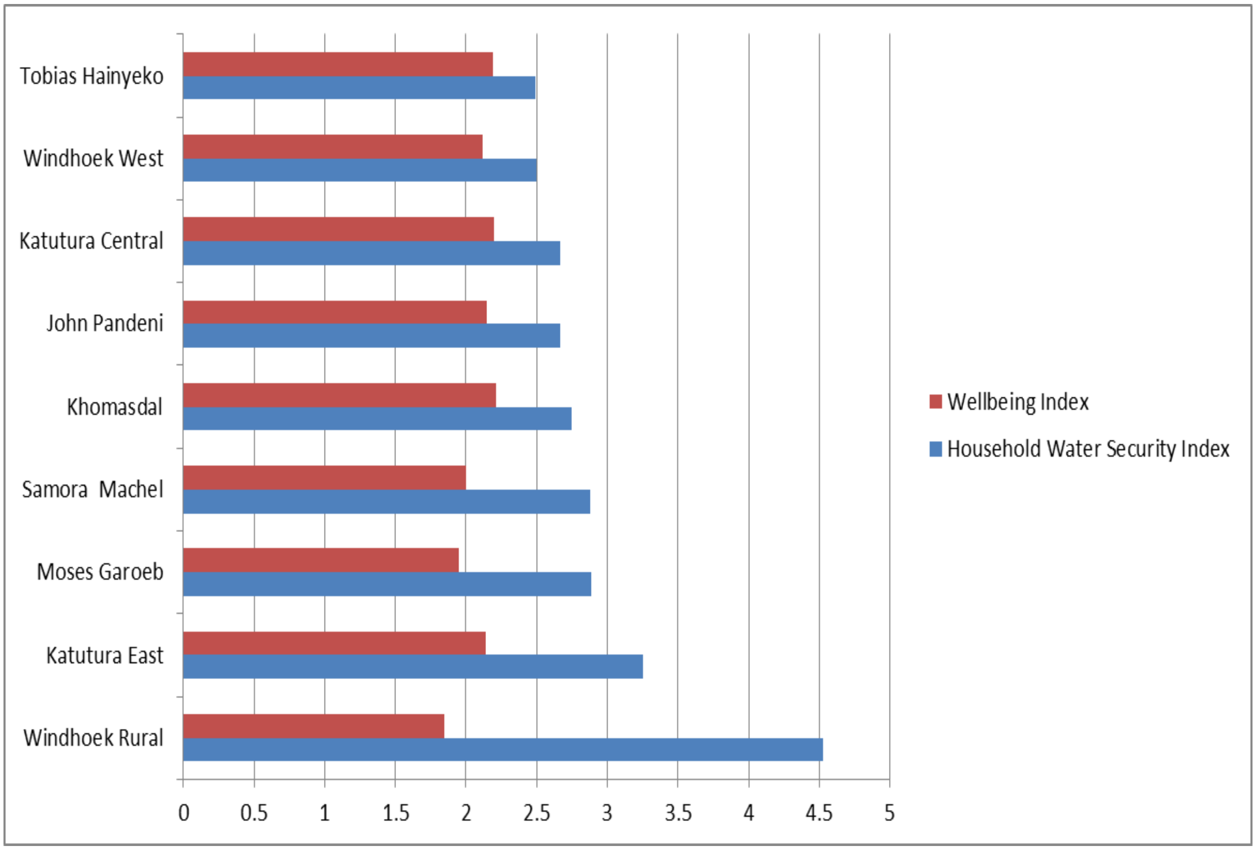


Figure 21: Household water security and well-being in Windhoek.

On the other hand, economic water security was regarded as moderate, by 69.2% of the households (Figure 20). This suggests that water security is crucial towards sustaining water related livelihoods in Windhoek. Figure 22 presents variation in economic water security across areas, using the Asian Water Outlook Framework. In most areas the water security is at the level of engaged. This suggests there is enough infrastructure in all communities to sustain livelihoods, however, in all areas the issues of adequacy, and perceived water safety may jeopardize the provisioning water ecosystem services in Windhoek.

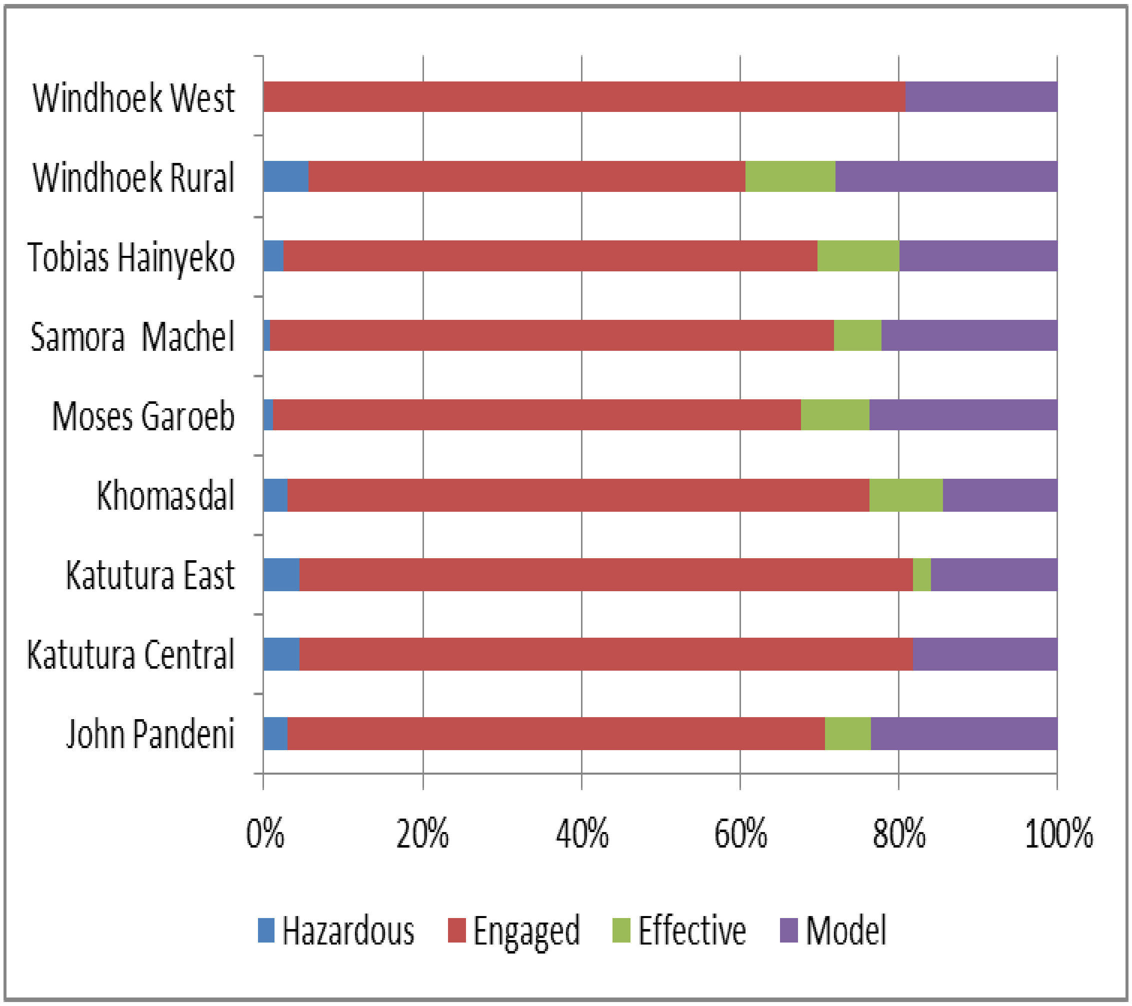


Figure 22: Economic water security variability in Windhoek

4.0 Conclusions

4.1 Governance

There are different ways in which diverse actors including but not limited to the government, private and public sector, and civil society at large interact and intervene to address issues that affect them. In this study, analysis of governance issues using elements of the concept of urban governance configuration proposed by Scott (2017) revealed that there are different actors that were involved in discussion and decision making to address the issue of water supply to industries, pollution from industrial effluent and the need to find diverse alternatives to the water insecurity problem. These City of Windhoek had a lion's share of decision making regarding addressing the problems highlighted. The analysis also reveals the step by step manner in which these issues of water were dealt with one at a time and that alternative solutions were sought as the problem took different form. Initial pollution and failure of oxidation ponds led to different solutions that were developed and implemented.

Analysis of Water Management Plan for City of Windhoek 2017 and Transformational Strategic Plan (2017-2022) for City of Windhoek policies revealed that despite being developed recently after the Namibia Climate Change Policy, Strategy and Action Plan had been enacted, very little climate change related issues are presented and used in these policies despite Windhoek. This suggests that there is high likelihood that even at CoW level most policies that are used have little climate change content or usage and application.

4.2 Water demand and supply

In conclusion, the Swakop river is a critical source of water to the Central Area of Namibia (CAN) which includes Windhoek. The river feeds the Swakoppoort Dam and Von Bach Dam which contribute about 70% of the water supply to Windhoek and surrounding areas. It was found that, the Swakop River is dry most of the year and only flows during periods of heavy rainfall. The drought periods with the longest duration were observed from 1978/79 to 1981/82 and between 2011/2012 to 2015/16 with an annual streamflow of less than 7.8 Mm^3 for a period of 4 years. Based on the selected threshold of 7.6Mm^3, drought periods with the highest intensities were observed in 1994/95, 2002/03 and 2012/2013 with a deficit of -7.21Mm^3, -6.65Mm^3 and -7.6Mm^3 respectively, making the 1994/1995 drought one of the most intense droughts over the recorded period. The monthly streamflow data for the Swakop River indicate that the river runs dry for most months in a year and some years were observed with more zero flows than others. The years 1994/1995 and 2002/2003 had the most zero flows. In view of the prevalence of drought of the Swakop River, the increase in water demand in Windhoek and surrounding areas due urban and rural population will mostly be affected during periods of severe droughts which are more cyclical. Therefore, plans to ensure the availability of sustainable water supply to Windhoek and surrounding towns should consider the prevalence of cyclical prevalence of drought of the Swakop River.

4.3 Livelihoods

Urban transformations in part as a consequence of rapid urbanization and emerging climate change may affect water security in African cities such as Windhoek. Considering the peculiar situation Windhoek finds itself in, being in a semi-arid zone, with low precipitation, it is imperative to critically examine water security for sustainable livelihoods. These may include:

(a) Water management including land management;
(b) Water use including built and natural infrastructure;
(c) Water demand stressors , including water for direct use- drinking, food production, sanitation, to design better water demand management mechanisms;

The water management goals should lead towards sustained ecosystem benefits to households and communities.

5.0 Future Directions

5.1 Governance

More extensive policy analysis must be carried to assess the extent to which Climate Change has been mainstreamed and more importantly how it is or should be applied during planning and decision making at city of Windhoek level to segment efforts of FRACTAL project.. More focused but extensive research should be conducted to assess potential for polluting the Klein river and Swakopport dam.

5.2 Water demand and supply

In view of the findings above, the effect of drought on the Swakop River was indeed observed. To ensure a holistic view of the effect of drought on the water supply to Windhoek and surroundings areas, the sensitivities of the water supply networks from the Karst Aquifer to Windhoek need to be analyzed under different climate change scenarios**.**

5.3 Livelihoods

This study should lead to a further studies that explore the synergies that water provisioning are linked to including food security and energy, as well as poverty reduction. The study should be extended to other African cities for comparison.

6.0. References

Broto, V.C., Macucule, D.A., Boyd, E., Ensor, J. and Allen, C., 2015. Building collaborative partnerships for climate change action in Maputo, Mozambique. Environment and Planning A, 47, 3, 571-58

Croker, K. M., Young, A. R., Zaidman, M. D., Gwyn, H., Croker, K. M., Young, A. R. & Rees, H. G. (2009). Flow duration curve estimation in ephemeral catchments in Portugal Flow duration curve estimation in ephemeral catchments in Portugal, *6667*. https://doi.org/10.1623/hysj.48.3.427.45287

Dalezios, N.R., & Bartzokas, A. (1995) *Daily precipitation variability in semi arid agricultural region*. Hydrol Sci J 40(5):569–585.

Earth Observatory (2011). https://earthobservatory.nasa.gov/NaturalHazards/view.php?id=50108. Retrieved 6 March 2018.

Kumar, M. N., Murthy, C. S., Sesha Sai, M. V. R. & Roy, P. S. (2010). *Analysis of Standardized Precipitation Index (SPI) data for drought assessment*. Hyderabad.

McKee, T. B., Nolan, D. J. & Kleist, J. (1993). The relationship of drought frequency and duration to time scales. Preprints of 8th Conference on Applied Climatology. Anaheim.

Mathieu, R. & Yves, R. (2003). Intensity and spatial extension of drought in South Africa at different time scales, Water SA Vol. 29 No. 4

Meigh, J., Tate, E. & Mccartney, M. (2002). Methods for identifying and monitoring river flow drought in southern Africa, (274), 181–188.

Peyroux, E., Scott, D., Baud, I. S. A., and Jameson, S. 2014. Spatial knowledge management and participatory governance: Rethinking the trajectories of urban, socioeconomic and environmental change and the politics of 'sustainability' in southern cities. Final analytical framework, Chance2Sustain, EADI.

Peyroux, E., Baud, I. S. A., Scott, D and Jameson, S. 2017. Draft paper on Governance Configurations for Sustainable Cities. (Unpublished)

Sung, J. H., & Chung, E. (2014). Development of streamflow drought severity – duration – frequency curves using the threshold level method, (1997), 3341–3351. https://doi.org/10.5194/hess-18-3341-2014

Woo, M. K. & Tarhule, A. (1994). Streamflow of Drought of Northern Nigerian Rivers. *Hydrological Sciences Journal*, 39(1), 19-34.