ASSESSMENT OF WATER FOOTPRINT FOR BETTER WATER MANAGEMENT IN OSHANA REGION, NAMIBIA.

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WATER RESOURCES MANAGEMENT

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ABSTRACT

Researchers have created a variety of water footprint concepts and technologies in response to growing concerns about the pressure on the world's water resources. Water footprint involves the direct and indirect water use of a consumer or a product. This study, therefore, examines the water footprint of an individual using the concept of water footprint and questionnaire survey to establish a better understanding of an individual's water demand for better management of water resources in the Oshana region. A simple random sample of 32 respondents from two constituencies in Oshana region was used. The water footprint calculator was used to determine the water footprint of individuals in the constituencies, and their variations among constituencies. The findings show that Ongwediva constituency is the largest water consumer in the region with a water footprint of 4079.19 m^3/capita/year whereas Okaku constituency is the least water consumer with a water footprint of 1726.50 m^3/capita/year. Furthermore, one-way ANOVA was performed to determine the relationships among the footprints in the two constituencies. The analysis shows a significance level of 0.001 indicating that the two constituencies varied significantly. Pearson correlation was used to determine the link between the water footprints of individuals and their socio-economic backgrounds. The results revealed that there was no correlation between water footprint and socioeconomic factors. The findings of the study revealed the need for public awareness on the use of water resources and incorporating water footprint in the water resources management policies for better water resources management.

Key words: direct water, water footprint, water scarcity, water use, virtual water

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…… I AM BECAUSE YOU ARE ……..

DEDICATION

This thesis is wholeheartedly dedicated to the memory of my late father, Isaak Paulus Kalulu. May his soul continue to rest in peace and may his memory forever be a comfort and a blessing.

DECLARATION

I, Salmi M.F Paulus, hereby declare that this study is my own work and is a true reflection of my research, and that this work, or any part thereof has not been submitted for a degree at any other institution.

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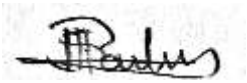
Salmi Paulus		April 2024
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LIST OF ABBREVIATIONS AND / OR ACRONYMS

ANOVA	Analysis of Variance
CEB	Cuvelai Etosha Basin
GIS	Geographical Information Systems
IHE	Institute for Water Education
IMD	Index of Multiple Deprivation
NIMD	The Namibian Index of Multiple Deprivation
SDG	Sustainable Development Goals
SPSS	Statistical Package for Social Sciences
UNAM	University of Namibia
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
VWC	Virtual Water Content
WF	Water Footprint
WRM	Water Resources Management

CHAPTER ONE

1.0 INTRODUCTION

1.1 Study Background

The world's water resources are under increasing demand due to the combination of the effects of climate change, increased human activities and the world's growing population. This has now created a dire need for better water management (Chapagain and Tickner, 2012; Muratoglu, 2019). Water is essential to all living things and the amount of water available for different areas is largely influenced by seasonal and geographical variations which further intensifies the need for management of water resources (Chapagain and Tickner, 2012). It is believed that agricultural activities consume most of the water. On average, around 8% of water is used domestically, 22% by industry, and 70% by agriculture on a global scale (Hoekstra and Chapagain, 2007).

An approximately 2.7 billion people around the world live in severe water scarcity and the issues such as the effects of a changing climate, making water more unpredictable and an intensified water scarcity as demand increases are the results of unintentional and excessive water use (Hoekstra, Chapagain and Zhang, 2015). Many countries are experiencing water scarcity as a result of unequal distribution of water resources and increased demand. As a result, improving water resource management and efficiency has become crucial. (Mekonnen and Hoekstra, 2011). As the demand for water resources have increased, the potential consequences of scarcity have become more obvious. As a matter of fact, water security has become

a crucial topic globally as water is essential to support a growing population and economic growth (Muratoglu, 2019).

Instruments of measurement that allow for comparison of water use must be implemented in order to address a worldwide problem (Zhu *et al.,* 2019). As a result, in the recent years, a group of researchers such as Dr. Arjen Y. Hoekstra, Dr. Mesfin M. Mekonnen and Professor Ashok K. Chapagain established the concept of water footprint to allow more accurate measurement of water use and consumption (Lee, 2019). The water footprint concept has grown in popularity as a tool for analyzing environmental issues related to water resource use and management. Among other environmental footprints, the footprint family includes the ecological footprint, carbon footprint, and water footprint (Hoekstra *et al.*, 2009). Water footprint is the direct and indirect water use of a consumer or producer. Water footprint assessment is an analytical method that can explain the connection between human activities and water scarcity and provide a creative strategy for managing integrated water resources. An individual or community's water footprint is the total amount of freshwater used to produce the goods and services that a person or community consumes (Hoekstra and Mekonnen, 2012; Zeng *et al.*, 2012). The idea of "water footprints" has grown in popularity as a tool for analyzing environmental problems related to the use and management of water resources.

A water footprint can be applied at different measures and contexts as it is a multidimensional indicator. Ercin and Hoekstra (2014) developed a method for estimating the future global water footprints based on the consumption patterns of

the consumers, population and economic growth, as well as production. Similarly, Lee *et al.* (2016) established a concept of water footprint and questionnaire survey to explore the sustainability of water management and to quantify environmental costs of an individual's water need. Shtull -Trauring *et al.* (2016) developed a water footprint methodology of integrating Geographical Information Systems (GIS) technology with water footprint to quantify the benefits of adopting site appropriate crops and agricultural practices that lowers water footprint by reducing consumption and minimising negative environmental impacts.

This study, therefore aims to establish a better understanding of an individual's water demand for better suggestions concerning the management of water resources in Oshana region, central Namibia, by applying the water footprint approach. The study further aligns to the 2030 Sustainable Development Goals (Berger *et al.*, 2021; Katila *et al.*, 2019). Overall, the study addresses goal 6: ensure availability and sustainable management of water and sanitation for all, and in specific target 6.4 that aims to "substantially increase water use efficiency across all sectors and ensure sustainable water withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity". The findings of this study can be employed to inform policy makers and water resources managers on better water resources management.

1.2 Statement of the problem

An individual can calculate their water footprint which allows them to understand their own water needs. However, a water footprint is easily misunderstood and misinterpreted due to the evolving methodologies and lack of information on the

general need of knowledge on how water is consumed and polluted. Previous research has found that the tremendous increase in water demand has resulted in an increasing scarcity of water in various parts of the world (Pahlow *et al.*, 2015). Water scarcity affects more than 40% of the world's population, according to Katila *et al*. (2019), and is mostly caused by stress on water supplies. Namibia is no exception to the world problem, because the country has been categorised as a water-stressed country with its water availability below 1000 cubic meters/person/day (Wallingford, 2003).

Despite the evolving body of research, there are no universal or one size fits all solutions to water problems. This is because of the influence of the surrounding environment, which in most cases differ from place to place. Hence the water problems need to be addressed within the context of the local settings (Egan, 2011; Hoekstra, Chapagain and Oel, 2019). Therefore, water management efforts can be enhanced by increasing the availability of local based knowledge. Without addressing the need for local based knowledge, water management actions will continue to be based on inaccurate information, and thus ineffective for their intended purposes. Without considerable improvements in water management, the globe will face significant issues in securing adequate water to maintain a growing population, promote economic growth, and meet environmental needs. As a result, water prices around the world would increase tremendously (Mekonnen, 2005).

Identifying the water footprints help with the understanding of water demands and can be used for future water management. Many water footprint studies focused primarily on crops, livestock, products, supply chain, human population, river basin and aquifers. Although human domestic and non-domestic activities consume a

significant quantity of water, there is limited literature on an individuals' water footprints.

1.3 Research Objectives

1.3.1 Main Objective

The main objective of the study was to establish an understanding of an individual water footprint, for consideration in the management of water resources in north central Namibia.

1.3.2 Specific Objectives

To achieve the main aim of this study, the following specific objectives were implemented:

1. To utilize a water footprint tool to determine individual's domestic water footprints.
2. To determine the variations in individuals' water footprints among constituencies.
3. To establish a link between individual's water footprint to socio-economic factors.

1.4 Hypotheses of the Study

1.4.1. Hypothesis 1

H_0: There is no significant difference between the water footprints of constituencies.

H_1: There is a significant difference between the water footprints of constituencies.

1.4.2. Hypothesis 2

H_0: There is no significant correlation between individual water footprint and socio-economic factors.

H_1: There is a significant correlation between individual water footprint and socio-economic factors.

1.5 Significance of the Study

More can be understood about the prevailing lifestyle in a region by observing individual water consumption, as it determines how human activities affect their water demands and natural environment. This is because human activities can pose a serious threat to the environment causing water scarcity if they are unsustainable. This study aimed to make a key contribution in this regard, by assessing and quantifying the water footprint of individuals to have a better understanding on the water demand and how it relates to socio economic development. This study will therefore contribute to the existing knowledge, and provide understanding on individual water consumption, and provide better suggestions concerning sustainability and management practices of water resources can be proposed. Therefore, there is a need to establish both current and future research to aid sustainable management of water resources. The findings of the study can be employed to provide water management stakeholders with an improved understanding of how much water is consumed between two economically distinct areas and stimulate policies and stakeholders in the water sector to be more efficient in water management.

1.6 Limitations of the study

Few challenges were experienced during data collection. Some respondents were reluctant to partake in the survey as they demanded some form of payment to participate. The researcher was suspicious that the respondents might have failed to answer with honesty, which might not accurately reflect the reality of all the participants. This might have influenced the overall results of the study. Due to the sample size of the study, the results are not generalizable beyond the specific population from which the sample was drawn. This was due to the short duration of the study, which limited the amount of information that could have been learned from participant interactions.

1.7 Delimitations of the study

Water footprint studies can be applied in different contexts like green marketing, product supply chain, a river basin, an aquifer or that of an individual. However, this study only focused on an individual's water footprint. This study did not fully examine the water footprint, despite the fact that doing so is crucial to understanding how human activities or particular products are related to problems with water scarcity and pollution. It also determines how human activities and products can become more sustainable from a water perspective. Although there are other issues of concern, this study focused only within the geographical boundaries of the Okaku and Ongwediva constituency in Oshana region. According to the results presented by Noble *et al*. (2001), Okaku constituency is ranked the highest in Oshana region that is most deprived of basic materials goods (television, radio, newspaper, telephone and computer), employment, education, and living

environment, whereas Ongwediva constituency is ranked lowest in Oshana region that is deprived of materials (television, radio, newspaper, telephone and computer), employment, education, and living environment.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Introduction

An individual's water consumption pattern and its implications on water resources are often evaluated by taking into account how much that person consumes (Debrah, 2011). Humans consume and contaminate huge amounts of water, with agricultural production consuming significant amounts of water consumed in the industrial and home sectors. Little emphasis has been given to the reality that overall water use ultimately depends on what and how much communities consume as well as the structure of the global economy that supplies the goods and services. The characteristics of a supply chain can be related to the amounts of water required in the manufacturing process since it has an impact on the end consumer product (Aldaya *et al*., 2011).

Given the world's constantly deteriorating situation as a result of the availability and value of freshwater resources, freshwater scarcity has been acknowledged as a worldwide issue of the utmost importance. Metrics that are used to track water use and the environmental implications of water consumption are becoming more relevant as a result of the pressure on finite water resources. One of the new measures that are a popular tool is the water footprint, similar to the "ecological footprint" concept first proposed by Rees and Wackernagel (1999), Hoekstra initially presented the idea of a water footprint in 2002 to quantify the human effect on freshwater resources (Herath, 2013). It was later explained by many experts in

the water sector (Chapagain and Tickner, 2012). A water footprint of a consumer/individual is therefore defined by Aldaya *et al.* (2011) as the entire amount of freshwater used and contaminated during the process of producing the goods and services that the consumer uses.

2.2 The Concept of Water Footprint

A consumer's or producer's water footprint, which considers both their direct and indirect water consumption, is a measure of how much freshwater they are using. Compared to the conventional and constrained measure of water withdrawal, the water footprint can be seen as a comprehensive indicator of the use of freshwater resources. The amount of freshwater needed to make a product, measured over the whole supply chain, is known as the product's "water footprint" (Aldaya *et al.*, 2011). It is an influential tool that determines the link between the consumption of water resources by humans, and can be calculated for any distinct group of consumers (e.g. an individual, family, village, city, province, state, or nation) or producers (e.g. private enterprise, public organization or economic sectors) (Debrah, 2011).

The individual's water footprint is a great communication tool for helping people comprehend the effects of their lifestyle on water resources. It shows how people's consumption of goods and services influences water resources, and an individual's water footprint is also used to instill a feeling of personal responsibility in them. They can alter their total personal impacts on the environment and water by making minor modifications to their consumption patterns and water footprint.

This water footprint categorizes the sources of the water used into three categories: green, blue, and grey. The rainwater consumed or infiltrated in the root zone and available for photosynthetic processes is shown by the green water footprint and it is lost through evapotranspiration. The ground and surface water are represented by the blue water footprint which is sometimes referred to as evaporated irrigation water. Grey water is water that has deteriorated from its initial quality as a result of contamination from numerous uses. The amount of water needed to remove pollutants from grey water so that it meets quality criteria as "normal" fresh water is represented by the grey water footprint (Mekonnen and Hoekstra, 2011). Figure 1 is an illustration of what is inclusive of a water footprint and what is not inclusive of a water footprint. The illustration also shows that non-consumptive water use is not part of the water footprint. Water that can be recycled and reused is included in non-consumptive water. The water that flows down the drain and into the sewer system, for instance, is cleansed and then dispersed for further use. Recycling water reduces overall water use. The illustration below further indicates that the water footprint includes green, blue, and grey water footprint as well as the indirect water use component (Aldaya *et al*., 2011).

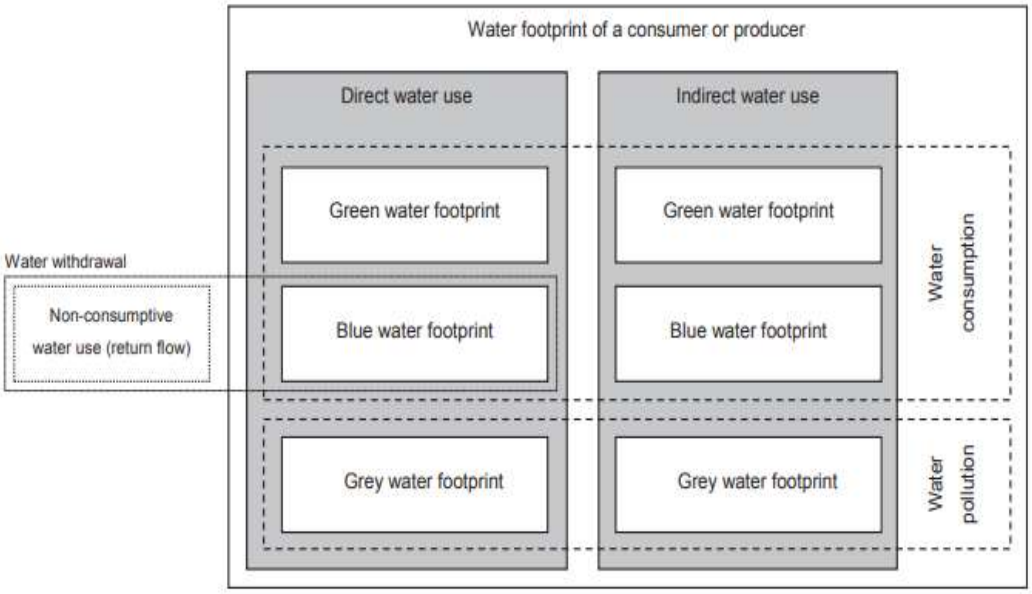

Figure 1: A schematic illustration of a water footprint component. (Adapted from Aldaya *et al*., 2011).

2.3 The Concept of Virtual Water Content

The idea of "virtual water content" serves as the foundation for water footprint computation as they are closely related. Virtual water content is defined as the volume of water needed to manufacture a product or the amount of water used in the production process of a product. Additionally, it is also known as water that is embodied in the product, including the water used in the manufacturing process (Xiuying, 2004). Under ideal circumstances, 1 cup of coffee corresponds to 140 litres, and 2700 litres of water is required to grow cotton to manufacture/produce a T-shirt. The concept has gained considerable traction in recent years among water professionals, and as a result, the studies' findings have tended to emphasize crops and livestock products that are considered food (Adetoro *et al.*, 2020).

2.4 Approaches for calculating water footprint

2.4.1 Top-down Approach

Two alternative methods, the top-down method, and the bottom-up method can be used to determine the water footprint.

In the top-down approach, also known as the production-based approach, the total national water use and the net virtual water import into the nation are added to determine the water footprint of that nation (Aldaya *et al*., 2011). It is calculated as water footprint of a nation using Eqn. (1):

$$WF_{const,\,nat} = WF_{area,\,nat} + V_i - V_e \qquad \text{[volume/time]} \qquad [1]$$

Where: $WF_{const,\,nat}$ is the national water footprint consumption,

$WF_{area,\,nat}$ is the water footprint within a nation,

V_i is the virtual water import

V_e is the virtual water export

2.4.2 Bottom-up Approach

Based on the input of consumption patterns, the water footprint can also be calculated. The bottom-up strategy is based on a technique for determining the water footprint of a group of consumers, in this case, the people who live in a country. Based on the input of consumption patterns, the water footprint can also be calculated. The bottom-up strategy is based on a technique for determining the water footprint of a group of consumers, in this case, the people who live in a country (Aldaya *et al*., 2011). The water footprint of national consumption is therefore calculated using Eqn. (2):

$WF_{const,\ nat} = WF_{cons,\ nat,\ dir} + WF_{cons,\ nat,\ indir}$ [volume/time] [2]

Where: $WF_{const,\ nat,}$ is the water footprint of national consumption,

$WF_{cons,\ nat,\ dir}$ is the direct water footprint of consumers within a nation,

$WF_{cons,\ nat,\ indir}$ is the indirect water footprint of consumers within a nation.

The term "direct water footprint" describes the water use and pollution caused by consumers at home or in the garden. The use of water by others to produce the goods and services that customers consume is referred to as their "indirect water footprint." It refers to the water utilized to manufacture, for instance, food, clothing, paper, energy, and industrial goods used in daily life (Xiuying, 2004).

2.5 Water footprint studies

In the literature, water footprint assessment studies are available globally. A global water foot printing on the impact of consumption and production due to freshwater scarcity was reported by (Ridoutt and Pfister, 2010). A global water footprint assessment on the green, blue and .grey water footprint of production and consumption was provided by (Mekonnen and Hoekstra, 2011). These are some of the earliest investigations into the water footprint of geographically defined regions. The majority of these studies make use of global data, but they fall short of providing a thorough evaluation of particular regions. Some researchers focused on basin catchment water footprints. The majority of the studies conducted thus far have been applied in Asian countries.

A web based water footprint calculator was developed by (Mekonnen, 2005). It serves as a teaching tool that produces consumption data using the limited

information that the user provides. An analysis of the water footprint and the virtual water concept has been studied by (Aldaya *et al.*, 2010) in the context of Spain's Mancha Occidental region, focusing on the hydrological and financial elements of agricultural production. This made a distinction between ground water and green and blue water. In order to measure the environmental costs associated with individual water needs, an assessment of personal water footprint was conducted in Yunlin County, Taiwan (Lee *et al.*, 2016). Personal water footprints are known to be influenced by practices related to water use.

Although the amount of research on water footprint has been growing rapidly, there are currently very few studies that use it as a tool for managing water resources (Kuiper *et al*., 2011). It is crucial to evaluate water footprints as a tool for water resources management as it assist in delivering sufficient water to get the maximum water efficiency and the highest return per cubic meter of water. (Mohamed and Mehaweed, 2021). To feed into a thorough national water accounting system, water footprint needs the integration of agriculture, trade, and water resources management strategies. One technique to analyze the effects of human activities, according to another study by (Vasconcellos, 2020), is to quantify the entire environmental stresses by measuring the footprint. Climate and resource issues are influenced by footprints, particularly when it comes to environmental initiatives.

Taiwan's Taipei city's ecological and water footprints have been evaluated by (Lee, 2019). Over the course of five months, a household survey was conducted face-to-face. Gender, age, education, and personal annual income were not related to ecological footprint and water footprint, according to the study's findings. Although

the study showed considerable differences in the ecological footprint and carbon footprint among Taipei's districts. Game-post Howell's hoc test was used to compare the water footprint and the built-up land footprint, and the results showed that the test was not significant. Despite the fact that each of Taipei's several districts has a unique ecological footprint, the research's conclusions demonstrate that there is no statistical correlation between a resident's ecological footprint or water footprint and his or her neighbourhood or social status. Lee (2019) encourages environmental programming in order to achieve environmental education goals and alter their daily spending patterns in order to reduce their ecological footprints.

In relation to a few chosen goods and services, the assessment and analysis of Ghana's water footprint was carried out by (Debrah, 2011). Only the consumptive portion of the water footprint was considered in the analysis. Four of the 13 crops taken into consideration were cash crops such as cereals (maize, millet, rice and sorghum) and tubers (Cassava, cocoyam, plantain and yam) with four cash crop (cocoa, coffee, cotton and tobacco). Data that was examined was for a duration of five years from 2001 to 2005. Ghana had an estimated annual water footprint of 24.84 billion cubic meters. 22.65 billion cubic meters per year, or 91.2% of the total water footprint, are used from local water resources, whereas 2.19 billion cubic meters per year come from foreign water sources.

Aldaya *et al.* (2011) gave a detailed explanation on the water footprint accounting methodology that is set out in the water footprint assessment manual. The

methodology was used to assess water footprint in South Africa by group of researchers (Pahlow *et al.,* 2015), it is noted that 75% of the total water footprint was contributed by crop production of the country's total production. Crop production is composed of maize, fodder crops, sugar cane, wheat, and sunflower seed, which amount to 83% of the crop water footprint. According to the study's findings, the average water footprint of a consumer in South Africa is 1 255 cubic meters/year, which is less than the global average of 1 385 cubic meters/year. There are significant issues with sustainability or significant river basins that experience severe blue water shortages throughout the year (Pahlow *et al.,* 2015). In order to dramatically minimize the water footprint of consumption, it was advised that the diet pattern be changed to include less meat.

CHAPTER THREE

3. METHODOLOGY

3.1 Introduction

This chapter briefly describes the study area and discuss the method employed to undertake the study. Furthermore, it outlines the research design, describes the population, sampling process, data collection and data analysis, as well as the procedures adopted in the study. It concludes with ethical procedures which were taken into consideration.

3.2 Study Area

The study was conducted among two selected constituencies in Oshana region namely Ongwediva and Okaku (Fig. 1 and 2) which are located in Namibia's far northern part. Oshana region is the smallest of Namibia's thirteen regions, located at a height of around 1100 meters above sea level, with an area of about 8682 km^2 and 176,674 inhabitants. It is located on the western side of the Etosha Pan within the Etosha National Park which forms part of the Cuvelai-basin (Kaundjua, Angula and Angombe, 2012). It lies between latitude -18º 01' 60.00" S and longitude 15º 44' 59.99" E. It shares boarders with Omusati region to the west, Oshikoto region to the east, Kunene region to the south and Ohangwena region to the north-east (Dieckmann and Otavi, 2014). The region is home to the Owambo ethnic group, which makes up the majority of Namibians. Despite the region's rural and urban features, the bulk of its residents are rural subsistence farmers (Niipare, Jordaan & Siyambango, 2022). The general salinity of the land and water consequently makes

this area sparsely populated with large metropolitan areas and settlements making it unsuitable for grazing or cultivation (Embashu *et al.*, 2013).

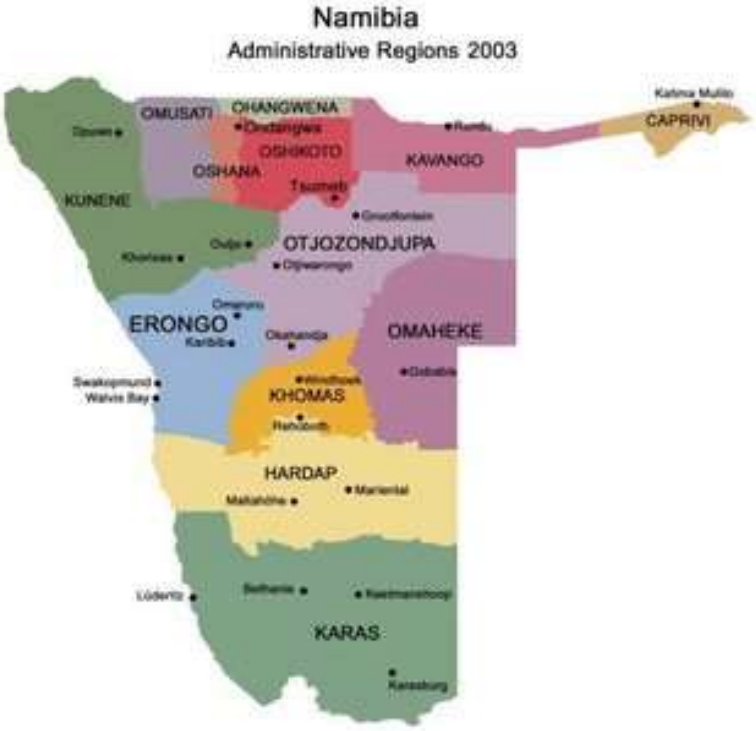

Figure 2: Location of Oshana region. (Adapted from Embashu *et al*., 2013).

Figure 3: Study area.
Source: Map produce by author in Arc Map, GIS.

3.2.1 Climate

The climate of the study area is similar to that of the Cuvelai Etosha Basin (CEB) because the region is located within the Cuvelai basin. The movement of air in the region is mostly governed by higher air pressure than their surroundings (high pressure systems) they are always forcing air away from them and into locations with lower pressure. They are frequently connected to the presence of clear blue skies. Conditions are only favourable for cloud development and rain during the summer months (November to April), when the high pressure systems have drifted south. Summers are usually hot, with average day temperatures above 33^{o} C and average night temperatures in winter can be as low as 6^{o} C (Embashu *et al.*, 2013). The topography is relatively flat with just a slight undulation brought on by the

iishana and the inter-fluvial hills made of Kalahari sand deposits. The vegetation of the area is characterised by a mosaic of grasslands and mopane shrubs, of which *Colophospermum mopane* is dominant. All types of life in the basin are significantly impacted by seasonal fluctuations. Little vegetation grows and the majority of surface water evaporates throughout the dry, chilly winter and the scorching, early summer months. The countryside then appears dry and desolate. Rainfall, which promotes the germination and growth of natural plants, causes all of this to shift (Mendelsohn *et al.*, 2013).

3.2.2 Surface water

The region is located in a semi-arid zone and is characterised by the Oshana flood plains of the Cuvelai drainage, annual flooding is common for a period of two to four months with an average annual rainfall ranging between 300-500 mm (Dieckmann and Otavi, 2014). The majority of the region's features are ephemeral; therefore, they occasionally contain water. Surface water is seasonal, dependent on where the rain has fallen for its occurrence, distribution, and extent. While major flooding is typically caused by extensive heavy rain in higher altitude and higher rainfall locations upstream in Angola, the local heavy rains in the area typically only generate localized flooding. The water table and soil permeability determine how long the surface waters last on average before evaporating or seeping away over weeks or months (Mendelsohn *et al.*, 2013).

3.2.3 Hydrogeology

Groundwater refers to rainwater or floodwater that has permeated the ground and been stored in water-bearing strata called aquifers. Aquifers in the area store ground

water as clearly tabulated in Table 1 indicating the quality of water in each aquifer system. Water will have accumulated over timescales ranging from years to thousands of years, depending on the type of aquifer. In areas with no other water supply, the water is very valuable. In those areas, ground water is essential for both people and livestock (Bittner and Kleczar, 2006). Aquifers of many sorts can be found in the CEB as indicated in Table 1. There are two types of aquifers: those that are confined and those that are unconfined. Six major aquifer systems exist in the CEB, some of which extend into the study area (Mendelsohn *et al.*, 2013). Oshana region is found to have a multi-layered aquifer, with a rock type of sand and limestone. The depth of the multi-layered aquifer is 10-80 metres with the quality of water known to be saline to hyper saline and yields the lowest of all aquifers in the CEB (1-30 yields/m^3/h).

Table 1. Characteristics of the aquifer systems. (Adapted from Mendelsohn *et al.*, 2013).

Aquifer system	Main rock type	Depth below surface in metres	Quality of water	Yield in cubic metres per hour
Ohangwena Multi-layered Aquifer	Sand, sandstone	60-300	Fresh to brackish	1-50
Oshivelo Multi-layered Aquifer	Conglomerate, sandstone, sand, dolocrete, calcrete	30-150	Fresh to brackish	5-100
Etosha Limestone Aquifer	Dolocrete, calcrete, sand	10-100	Fresh, locally high nitrate concentrations	3-100
Oshana Multi-layered Aquifer	Sand, calcrete/limestone	10-80	Saline to hyper saline	1-30
Omusati Multi-zoned Aquifer	Sand, clay and calcrete, dolocrete	10-50	Brackish, freshwater in places	1-30
Otavi Dolomite Aquifer	Dolomite	20-250	Fresh	More than 50

3.3 Research Design

The study employed a mixed-methods research whereby the researcher collected and analysed both quantitative and qualitative data within the same study. The mixed-methods of research offers a logical foundation, methodological flexibility and an in-depth understanding of smaller cases (Dawadi, Shrestha & Giri, 2021). To determine if individuals are sustainably managing water in north central Namibia, a water footprint calculator developed by Mekonnen (2005) was used to gain an in-depth understanding of the problem under investigation.

3.4 Population

The population of the study was comprised of individuals residing in Ongwediva and Okaku constituency. The study targeted members of households over the age of 18. The rationale for selecting these population was mainly due to socio-economic factors of poverty in the region, using the Namibian Index of Multiple Deprivation (NIMD) where Ongwediva is ranked low in the Index of Multiple Deprivation (IMD), whereas Okaku is ranked high (Noble *et al*., 2001). This therefore provided more insight of the relation between socio-economic background of an individual and how they consume their water.

3.5 Sample and Sampling Procedure

Sampling is defined by Radhakrishnan (2014) as a process of choosing a section of a population to represent the complete population. A sample can immediately give important information about a population. However, no sample can guarantee the exact representative of the population from which it was taken. Mujere (2016)

indicates that a sample size should be large enough to ensure that the results are statistically significant but also not so large that one could have achieved the same results with a much smaller size. Mujere (2016) further explained that a sample less than 100 may be sufficient if the main analysis is computing averages and comparing differences in a project. Ott (2015) indicates that at least 30 participants in a project are considered sufficient and a large sample size for many researchers. This research study therefore adopted the theory set by Ott (2015) by selecting a sample size of 16 participants from each constituency which added up to 32 participants. A simple random sample was used throughout the study for every individual to have equal chance to be included in the study as shown in Table 2.

Table 2. Questionnaire surveys conducted in different constituencies

Constituency	**Village/Location**	**Households (n)**
Okaku Constituency	Okandongwena	2
	Onyelelo	2
	Ofudheni	2
	Okadhimeti	2
	Ompunda	2
	Itananga	2
	Onakamwandi	2
	Elyambala	2
	Sub-total	**16**
Ongwediva constituency	Valombola	2
	Omatando	2
	Okatope	2
	Extention 11	2
	Old Ongwediva	2
	Efidi Lyomulunga	2
	Hannover	2
	Oshinyadhila	2
	Sub-total	**16**
Total		**32**

3.6 Research Instrument

The application of semi-structured questionnaires with a single visit was used in the study. This approach was used to gather empirical knowledge, estimations and water needs of individuals. The questionnaires were developed by the researcher, and the contents were taken mainly from the Personal calculator - extended (waterfootprint.org) water footprint calculator. The web based calculator was developed by Mekonnen (2005) a researcher at UNESCO-IHE.

3.6.1 Questionnaire

The survey process started off with a consultation with the village headmen to outline the purpose of the visit. The survey was conducted between the months of August 2022 and September 2022 with a total of 32 respondents. The questionnaire in this study was focused on the respondent's socio-economic status daily consumption of food, domestic water use (indoors) and domestic water use (outdoors) (Appendix 5).

Respondents were asked to provide information on socio economic status (gender, age, level of education, employment status, income), food consumption (daily food intake, preferences of sugar and fat intake, daily intake of coffee and tea). Indoor domestic water use (number of times laundry is done weekly, number of times dish washer is used, types of shower heads, number of daily showers, how many times baths are taken weekly, type of toilet) and outdoor domestic water use (means of washing car weekly, time spent watering garden, time spent on rinsing equipment).

With regard to food consumption, the respondents were asked to specify their diets for the previous week. Respondents who could remember their food consumption of the previous week were asked to answer the questions in the questionnaire. Respondents who could not remember their diet intake in detail were asked to provide their daily intake of each type of food. Daily intakes were eventually multiplied by seven to obtain a weekly intake.

The six paged semi structured questionnaire contents were prepared in advance and was revised before the survey was conducted. The questionnaire survey was conducted over a consecutive basis on different randomly selected households within the specified study areas. The questionnaire was double checked by a field assistant to identify any omissions and misinterpretations.

3.6.2 Water Footprint Calculator

The water footprint calculator is a tool that is based on a life cycle thinking approach. Meaning that it considers the impacts occurring along the entire life cycle of the products and the energy that is consumed (Gómez, Durán and Robina, 2020). The aim of the calculator is to educate people as to the impacts of their lifestyle on the scarce water resource (Lee, 2019). Water footprint calculator (Fig. 4) provides a snapshot of how daily activities and routines impact water use. The calculator is structured in such a way that data from a database and information provided by users are integrated, and feedback is sent to the users. There are two parts to the calculator. The average water footprint per person for the chosen nation is given in the first part. Users must enter their country of residency and select between two consumer types vegetarian and non-vegetarian in order to obtain the country's

average water footprint (Xiuying, 2004). After providing the necessary data, the server replies with the average water footprint per person across the country. In the second part, questions about income and the proportion of spending on industrial goods to income are used to gather data about people's consumption habits to determine the industrial water footprint. Further, the user can select several parameters depending on the level of detail required in the data regarding food water footprint to get their individual water footprint (Xiuying, 2004). The results reported as water footprint is meant to be an estimate that can help better understand the habits and behaviour of an individual and serve as a starting point from which individuals are obliged to reduce their impact on the water resource (Lee, 2019). It also tells how individuals contribute to the overall water footprint. The value of the water footprint calculator lies in its ability to help people understand how they use water not to provide an accurate accounting of water use like the one gained from a water audit, but to inform them of ways they might use water more sparingly. The calculations used in the water footprint calculator will be estimates of an individual’s water footprint (Hoekstra *et al.*, 2009).

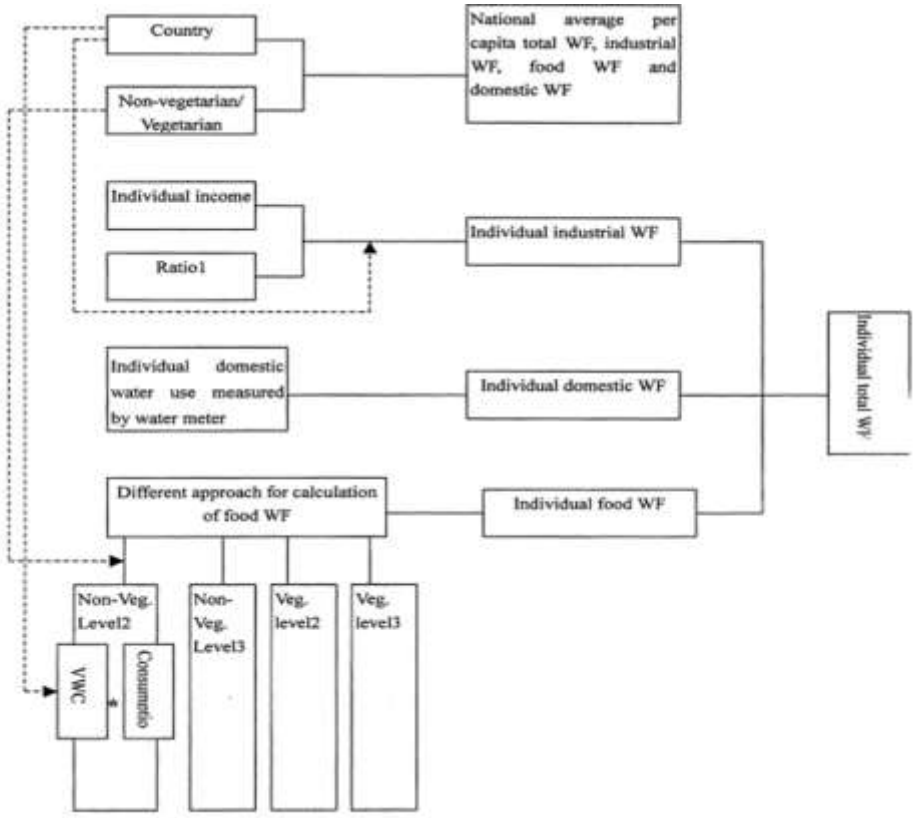

Figure 4. An illustration of a water footprint calculator. (Adapted from Xiuying, 2004).

3.7 Data Collection Procedure

Both quantitative and qualitative data was obtained through the questionnaire survey. The study documents the individual use of water at household level to determine their water footprint using a web-based calculator. The questionnaires were self-administered by the participants over the age of 18. The questionnaires were prepared in English and for participants that did not know how to read or those that were visually challenged, an interview was conducted. The questions in the questionnaire was translated in a language that was best understood by the participants to have a clear understanding of the questions. A total of 32 households were randomly selected to participate in the survey from two constituencies. The

field work was carried out in two phases. The first phase (August 2022) focused on the communities from Ongwediva constituency. The second phase (September 2022) focused on the Okaku constituency. The selection of these communities was based on the socio-economic factors or based on the fact that it is important to identify the differentials in the perceptions of water usage between the various social groups. The individuals were selected using a simple random sample method depending on the participant willingness to participate, where individuals were available during the time of the study. Permission to conduct the study was granted through the office of regional council of Oshana region, and the headmen of the villages.

3.8 Data analysis

The qualitative data collected was encoded before entering them into the water footprint calculator to determine the water footprint of individuals in order to fulfil the first objective of the study. After obtaining the individual water footprint results, the water footprint calculator was used to produce the average water footprint of the two constituencies in order to fulfil the second objective of the study which was to determine the annual water footprints variation of individuals among constituencies. The data was analysed using Statistical Package for the Social Science (SPSS) software to produce graphs and descriptive statistics of frequency, mean and standard deviation to describe the per capita daily water footprint in each constituency. For quantitative data analysis, a Pearson correlation was used to measure the correlation between individual water footprint and socio-economic background and a t-test was used to determine the significant correlation between

individual water footprint and socio-economic background. A level of significance used is a 0.05 *p*-value.

3.9 Research ethics

Mack and Woodsong (2005) describes research ethics as a way of dealing primarily with the interaction between researchers and the people they study. For this study, the research activities considered the ethical standards in respect to human lives, the environment and the laws of the university of Namibia. An ethical clearance certificate to conduct the study was obtained from the University of Namibia. Then permission to carry out the study in the constituencies was acquired from Oshana regional office, constituency offices and traditional authorities. After obtaining permission, the researcher then started to conduct formal household visits in the selected constituencies. The participants were informed about the research in a way that they could understand. The researcher got informed consent from the participants and they were assured of their rights to withdraw from the survey if they so wished to at any time during the data collection period without any explanation or facing any consequences. The identities of the participants were kept anonymous by excluding their personal details such as name, surname and contact details.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and discussion from the analysed data collected during the study. The study focused primarily on the use of a web-based water calculator to determine the daily water footprints of individuals residing in two constituencies in Oshana region. The study also took into account three components of a water footprint (WF) (food consumption, domestic water use and industrial water use).

4.2 Water footprint

The first objective was to use a water footprint tool to determine individual domestic water footprint. A sample size of 16 participants from each constituency, totalling 32 participants was employed. A simple random sampling technique was used to ensure equal representation. Semi structured questionnaires were administered to collect empirical knowledge, estimations, and water usage information from participants. After data was collected using questionnaires and encoded, the responses were entered into a water footprint calculator to determine the direct annual water use, virtual water use, and water footprint results (Table 3) (Figure 4). The respondents were asked about their daily water use, which was classified as domestic water use (direct) and virtual water use (indirect). Domestic water use (direct) is the use of water in everyday life for bathing, car wash, cooking, washing dishes, washing clothes, flushing the toilet, gardening, filling a swimming pool and other tasks. These were the

main basis for the calculation of daily water use (direct). Virtual water use (indirect) is the use of water that is consumed in the production of goods which includes growing agricultural products and in manufacturing industrial products. The information on a person's diet, the quantity of food consumed, and other hidden water consumption was used to calculate virtual water. The Water Footprint Calculator was used to convert these values into water footprints. The water footprint used is based on a life cycle thinking approach, considering impacts along the entire life cycle of products and energy consumed. A water footprint software serves as an informative and interactive tool that enables individuals and organisations to quantify, analyse, and better comprehend their water consumption patterns. It empowers users to make informed decisions and take steps towards more sustainable water use practices. It also aims to educate individuals about their water usage habits and the impact on water resources. The WF calculation is extremely simplistic and does not account for many details that may be reflected in an individual's lifestyle (Xiuying, 2004).

The mean annual WF per capita in Okaku constituency is presented in Table 3 and Figure 4 respectively. The results indicated that Onakamwandi village had the highest annual mean direct water use (368.50 m^3/capita/year) and Itananga & Onyelelo villages both had the lowest (34.00 m^3/capita/year). Onyelelo village had the highest annual mean virtual water use (indirect water use) (2118.00 m^3/capita/year) and Okadhimeti village had the lowest (994.50 m^3/capita/year). The total annual water footprint is obtained by adding direct water footprints to indirect water footprint for a certain location. Ofudheni

village had the highest annual mean water footprint (2165.50 m^3/capita/year) and Elyambala village had the lowest annual mean water footprint (1093.50 m^3/capita/year).

Table 3. Per Capita annual water footprint in 8 villages of Okaku constituency.

Villages	**Direct water use/ year (m^3)**	**Virtual/indirect water use/year (m^3)**	**Annual water footprint (m^3)**
Okandongwena	191.50	1567.50	1759.00
Onyelelo	34.00	2118.00	2152.00
Ofudheni	73.50	2092.00	2165.50
Okadhimeti	137.50	994.5.00	1132.00
Ompunda	77.00	1979.00	2056.00
Itananga	34.00	1552.00	1586.00
Onakamwandi	368.50	1499.50	1868.00
Elyambala	54.00	1039.50	1093.50
Average	**121.25**	**1605.25**	**1726.50**

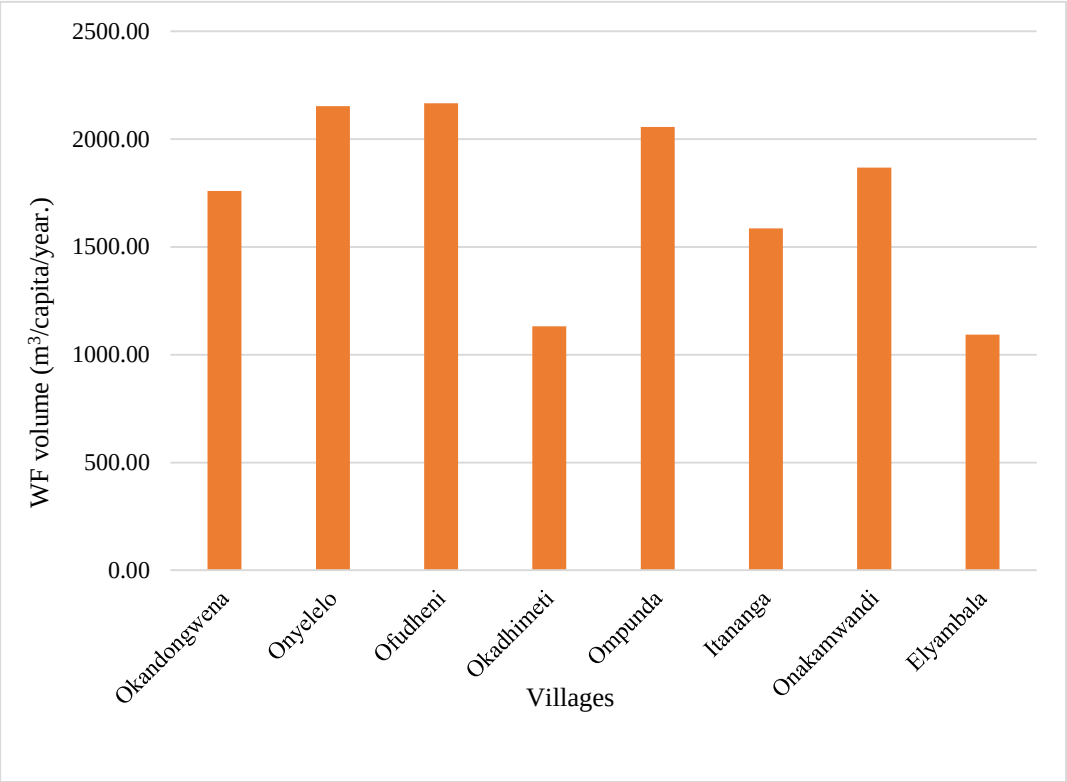

Figure 5. Mean WF values (m^3/capita/year.) for different villages in Okaku constituency.

A 1000 m^3 water footprint would suggest that in order to support the average individual's consumption on food, industrial products, and home water use in that nation for a year, 1000 m^3 of water would be required (Xiuying, 2004). The mean annual WF per capita in Ongwediva constituency is presented in Table 4 and Figure 5 respectively. The results indicate that Omatando had the highest annual mean direct water use (254.50 m^3/capita/year) and Old Ongwediva had the lowest (79.00 m^3/capita/year). Hannover had the highest annual mean virtual water use (indirect water use) (6119.50 m^3/capita/year) and Okatope had the lowest (2066.00 m^3/capita/year). Hannover had the

highest annual mean water footprint (6324.50 m^3/capita/year) and Okatope had the lowest annual mean water footprint (2212.00 m^3/capita/year).

Table 4. Per Capita annual water footprint in locations of Ongwediva constituency.

Locations	Direct water use/year (m^3)	Virtual/indirect water use/year (m^3)	Annual water footprint (m^3)
Valombola	123.50	2600.00	2723.50
Omatando	254.50	4941.50	5196.00
Okatope	146.00	2066.00	2212.00
Extension 11	131.50	4563.00	4694.50
Old Ongwediva	79.00	4187.00	4266.00
Efidi Lyomulunga	156.00	3321.50	3477.50
Hannover	205.00	6119.50	6324.50
Oshinyadhila	142.00	3597.50	3739.50
Average	**154.69**	**3924.50**	**4079.19**

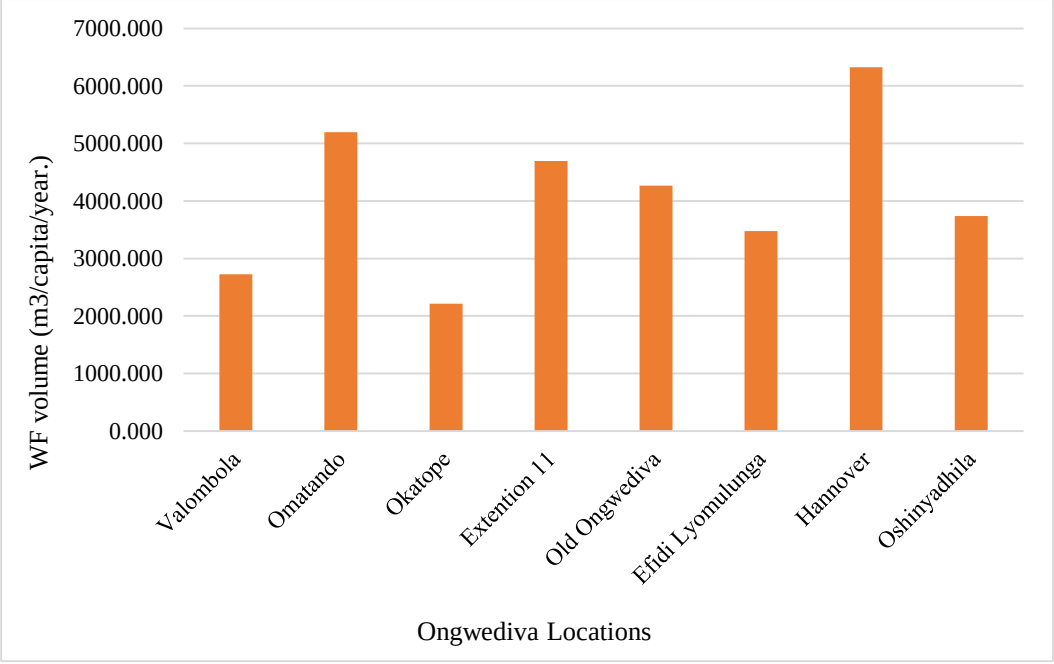

Figure 6. Mean WF values (m^3/capita/year.) for different locations in Ongwediva constituency.

An individual's consumption decision is influenced by a variety of factors which may include but are not limited to the individual's interest, quality, taste, price, income, lifestyle and socially rooted motives such as self-identity, social context, environmental and social concerns and culture. The ability to produce food is one of the most important factors influencing food consumption patterns. Because food is a normal good, an increase in income leads to an increase in food expenditures. Food demand is expected to rise in developing countries as income rises (Lee, 2019). The results indicated that an increase in income has contributed to an increase in consumption which further increase the water footprint of an individual. However, depending on a country's economic status, the impact of income on consumption trends may vary (Mekonnen, 2005).

4.3 WF variation among constituencies

4.3.1 Average water footprint variation

The second objective aimed to determine variations in water footprints among constituencies. Water footprint tend to vary in geographically delineated areas that economically vary (Mekonnen, 2005). Okaku and Ongwediva constituencies are no different from the areas mentioned by Mekonnen. The variation results of the average water footprint between constituencies is presented in Table 5. The results presented indicate that, Ongwediva constituency has a higher water footprint (4079.19 m^3/capita/year), whereas Okaku constituency has a lower water footprint (1726.50 m^3/capita/year). The

mean plots (Appendix 7) determine if the annual water footprint means varies between Ongwediva and Okaku Constituency.

Table 5: Average per capita annual water footprint variation between constituencies.

Constituency	**Direct water use/year (m^3)**	**Virtual/indirect water use/year (m^3)**	**Annual water footprint (m^3)**
Ongwediva (Urban)	154.69	3924.50	4079.19
Okaku (rural)	121.25	1605.25	1726.50

The type of area has a varied impact on the water footprint of each individual. It has been found that urban residents generally eat more high quality foods than the rural counterparts (Mekonnen, 2005). A study conducted by Lee (2019) indicated that urban residents tend to have a bigger water footprint than those in rural areas. The results obtained from this study however supports the statement spelled out by the previous researchers on the effects of location on water footprint.

4.3.2 ANOVA of water footprint

The one-way ANOVA was applied to the annual water footprint of the two constituencies. The null hypothesis states that there is no significant difference between the water footprints of constituencies. The results in Table 6 of Analysis of Variance revealed that the variation among water footprint and

constituencies were significant ($p < 0.05$) at the levels of $p = 0.001$, hence the null hypothesis was rejected.

Table 6. Analysis of Variance

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	22140553.891	1	22140553.891	22.492	<0.001
Within Groups	13781179.469	14	984369.962		
Total	35921733.359	15			

4.3.3 Correlation of water footprint between constituencies

A correlations table indicates the connections between two constituencies as indicated in Table 7. The Pearson correlation coefficient for the type of area (urban/rural constituencies) and annual water footprint is 0.785, which is not significant ($p < 0.001$ for a two-tailed test), based on 16 observations. Based on the results, the researcher states that the type of area (urban/rural constituencies) and annual water footprint have a statistically significant linear relationship ($r = 0.785$, $p < 0.001$). The direction of the relationship is positive (i.e. water footprint and the type of area (constituency are positively correlated)), meaning that these variables tend to increase together (i.e. the type of area is associated with greater water footprint). The magnitude, or strength, of the association is large ($0.5 < r = 0.785$).

Table 7. Correlations table showing the connections between constituencies.

		Type of area	Annual water footprint
Type of area	Pearson Correlation	1	0.785**
	Sig. (2-tailed)		<.001
	N	16	16
Annual water footprint	Pearson Correlation	0.785**	1
	Sig. (2-tailed)	<.001	
	N	16	16

**. Correlation is significant at the 0.01 level (2-tailed).

4.4 Link Between Individual's Water Footprint to Socio-Economic Background

4.4.1 Association between water footprint and socio-economic factors

The third objective was to establish a link between an individual's water footprint and socio economic factors. A multiple linear regression has been conducted with annual water footprint as the dependent variable, and gender, age, level of education, occupation and yearly income as five of the independent variables. Looking at Table 8, the significance value shows 0.016 meaning that this regression model was significant as a whole. R from the model summary that briefly explains the association between water footprint and socio-economic factors has a value of 0.631. The output of the regression model has shown that there is evidence in the data for a positive linear relationship between water footprint and socio-economic aspects.

Table 8. Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.631[a]	.398	0.282	1449.271	0.398	3.435	5	26	0.016

a. Predictors: (Constant), Yearly income (N$), Age, Gender, Level of education, Occupation

4.4.2 ANOVA of water footprint and socioeconomic background

The significance value as shown in Table 9 is 0.016. This therefore means that the null hypothesis is rejected (H_0: There is no significant correlation between individual water footprint and socio-economic background). This however opposes the results derived from a study conducted by Lee (2019) that socio economic factors did not affect the individual water footprint of individuals. However, another study conducted by Mekonnen (2005) indicated that not all socio economic factors such as age, income, place of residence (urban/rural), sex, are related to water footprint of an individual. Overall, the effect of income, age and dietary habit on an individual water footprint is higher as compared to other factors.

Table 9. Analysis of variance

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	36078974.406	5	7215794.881	3.435	0.016[b]
	Residual	54610011.813	26	2100385.070		
	Total	90688986.219	31			

a. Dependent Variable: Annual water footprint (m^3)

b. Predictors: (Constant), Yearly income (N$), Age, Gender, Level of education, Occupation

4.4.3 Regression coefficient

The regression coefficients are shown in Table 10. The constant indicated in the regression coefficient table represents the outcome of the dependent

variable in the case of all independent variables having a value of zero. Furthermore, the five independent variables are measured to what extend they correspond with the dependent variable. Visible, is the regression coefficient for level of education which has a relatively larger regression coefficient and a significance level of 0.003. The other independent variables (age, yearly income, occupation and gender) have generated an insignificant result. This means that the independent variables cannot be interpreted to have a linear relationship with the dependent variable (annual water footprint). The outcome of analysis in this report support the study conducted by Mekonnen (2005) that some socio-economic factors are not related to individual water footprint.

Table 10. Regression Coefficients

	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
(Constant)	987.477	1482.514		0.666	0.511	-2059.875	4034.829		
Age	9.773	18.890	0.086	0.517	0.609	-29.057	48.603	0.831	1.203
Yearly income (N$)	78.406	72.019	0.175	1.089	0.286	-69.632	226.443	0.893	1.120
Occupation	294.184	209.636	0.270	1.403	0.172	-136.729	725.097	0.625	1.600
Level of education	566.705	176.411	0.601	3.212	0.003	204.087	929.323	0.662	1.511
Gender	-1019.618	545.436	-0.302	-1.869	0.073	-2140.777	101.541	0.886	1.129

a. Dependent Variable: Annual water footprint (m^3)

4.4.4 Correlation matrix of water footprint and socioeconomic factors

The results of the correlation coefficient for different variables is called the correlation matrix and it is shown in Table 11. From this, it is evident that there is no strong relation between the age of an individual, income, occupation and gender. An increase in the four independent variables will not cause an increase in the water footprint of an individual. However, there is a strong relation between the level of education and individual water footprint. An

increase in the level of education will cause an increase in consumption and a shift in the food preference from low value foods to high value foods. Therefore, the increase in water footprint from the level of education can be attributed to both the increase in consumption level and causes a shift in food preference.

Table 11. Correlations Matrix

		Annual water footprint (m^3)	Age	Yearly income (N$)	Occupation	Level of education	Gender
Pearson Correlation	Annual water footprint (m^3)	1.000	-0.084	0.255	-0.122	0.525	-0.257
	Age	-0.084	1.000	-0.077	-0.258	-0.063	0.163
	Yearly income (N$)	0.255	-0.077	1.000	-0.077	0.259	0.160
	Occupation	-0.122	-0.258	-0.077	1.000	-0.507	0.171
	Level of education	0.525	-0.063	0.259	-0.507	1.000	-0.071
	Gender	-0.257	0.163	0.160	0.171	-0.071	1.000
Sig. (1-tailed)	Annual water footprint (m^3)		0.325	0.080	0.253	0.001	0.078
	Age	0.325		0.339	0.077	0.366	0.187
	Yearly income (N$)	0.080	0.339		0.337	0.076	0.191
	Occupation	0.253	0.077	0.337		0.002	0.175
	Level of education	0.001	0.366	0.076	0.002		0.349
	Gender	0.078	0.187	0.191	0.175	0.349	

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSION

Prior work has documented more agricultural water footprint studies. However, there has been a tremendous increase in the body of literature related to the study of commercial and industrial water footprints which rapidly surpasses that of agricultural water footprint (Hoekstra *et al*, 2015). Even so, these studies have not focused on water footprints of individuals that is associated with personal habits. This study therefore provides a quantitative analysis of the relationship between human consumption behaviour and water supplies for better management of water resources using a web-based water footprint calculator.

The water footprint is an effective indicator for demonstrating the connection between human usage and water resources. It calculates the quantity of water resources needed to support the way of life of any population size, whether an individual or an entire nation. The water footprint of an individual is broken down into three parts, depending on the categories of water use: the water footprint associated with food consumption, the water footprint associated with domestic water use, and the water footprint associated with the consumption of water utilized for industrial production. The largest share of the water footprint comes from food consumption.

Water footprint tend to vary in geographically defined areas. The variation results of the average water footprint between constituencies indicates that Ongwediva constituency has a higher water footprint (4079.19 m^3/person/year) whereas, Okaku

constituency has a lower water footprint (1726.50 m^3/person/year). The type of place has a different impact on each individual's water footprint, with urban people having a larger water footprint than those in rural settings. Different urban and rural development trends can be seen in Ongwediva and Okaku constituency. Ongwediva is Oshana region's second capital. It has well-developed commercial and industrial areas, as well as active living functions. Ongwediva constituency's water supply and remediation services are more advanced than those in Okaku constituency. It has more developed tertiary industries than Okaku constituency, such as accommodation, food and beverage industries. Individuals in the Ongwediva constituency are likely to increase their water footprints as a result of these industrial conditions and water resource-related benefits.

Age and income of an individual play a significant role among the factors that influence consumption and have an impact on the dietary habits of the individual. An individual's consumption habits and water footprint changes over the course of their lives. The water footprint rises from childhood to middle life before declining subsequently.

Individual income influences eating habits and consumption volume. A rise in income leads to an increase in consumption volume and a shift in dietary preferences away from low-value foods. As a result, the influence of income on water footprint is significant. Income and water footprint have a post and linear relationship.

5.2 RECOMMENDATION

Based on the findings of the study, the following recommendations are made:

1. It is necessary to make the water footprint calculator more interactive in order to highlight how different consumption habits affect the water footprint. This needs to be enhanced so that the impact of various water footprint reduction strategies may be measured.

2. To determine national water usage, a national water footprint must be conducted. It is vital to estimate the national water footprint in order to improve water resource planning and therefore Water Resources Management (WRM). A government's understanding of its national water footprint and the extent to which it is caused by consumption habits or inefficient production can assist them prioritize policy activities like altering consumption habits or increasing industry's water efficiency.

3. Further studies on water footprints at household level need to be conducted to provide more understanding on the water footprint concept. With more studies, individuals can understand how their habits and lifestyles fit into the greater context, contribute to problems, and how they can become a part of the solution with the use of a concept like the water footprint.

4. Communities and decision makers need to be educated on the concepts of water footprint, virtual water, sustainability of limited water resources and implications of consumption habits to aid in policy making.

5. Future water footprint studies need to extend the period of data collection, as data collection over a longer period improves efficiency and aids in removing uncertainty.

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APPENDICES

Appendix 1. Ethical Clearance Certificate

ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: JED0722 Date: 20 June 2022

This Ethical Clearance Certificate is issued by the University of Namibia Ethics Committee (REC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines. Ethical approval is given in respect of undertakings contained in the Research Project outlined below. This Certificate is issued on the recommendations of the ethical evaluation done by the ethics committee.

Title of Project: ASSESSMENT OF WATER FOOTPRINT FOR BETTER WATER MANAGEMENT IN OSHANA REGION, NAMIBIA.

Principal researchers: Ms. Salmi Paulus
Staff Number/ Student number: 201055007
Remarks:
Centre for Research Services

Take note of the following:

1. Any significant changes in the conditions or undertakings outlined in the approved Proposal must be communicated to the ethics committee. An application to make amendments may be necessary.
2. Any breaches of ethical undertakings or practices that have an impact on ethical conduct of the research must be reported to the ethics committee
3. The Principal Researcher must report issues of ethical compliance to the ethics committee (through the Chairperson) at the end of the Project or as may be requested by the ethics committee
4. The ethics committee retains the right to:
   i) Withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected,
   ii) Request for an ethical compliance report at any point during the course of the research.

The ethics committee wishes you the best in your research.

_____
Dr. Erasmus Shaanika (Chairperson: Decentralized Ethics Committee)

_____
Prof. Davis Mumbengegwi (Head, Multidisciplinary Research)

Appendix 2. Permission to conduct survey

REPUBLIC OF NAMIBIA

OSHANA REGIONAL COUNCIL
HUMAN RESOURCES MANAGEMENT

Private Bag 5543

Tel: 065 - 2288200

Oshakati, Namibia

Fax: 065 - 221 292
E-mail ramushembe@oshanarc.goy.na

Enquiries: Regina N Amushembe

Ref: 16/10 |
31 March 2022

Ms. Salmi Paulus
Cell: +264 81 862 0 429
Email: sallypaulus48@gmail.com

Dear Ms. Paulus

SUBJECT: PERMISSION TO CARRY OUT RESEARCH IN THE OSHANA REGION
We acknowledge receipt and refer to your letter dated 26 March 2022 for a request to carry out research (Master of Science (MSc) in Water Resources Management).

This letter serves to inform you that permission is hereby granted for you to carry out research on: Personal Water Footprint: Ongwediva and Okaku Constituencies in Oshana Region.

It will be appreciated if after completion of your field study, you share your findings with this office.

We wish you all the best in your study

Yours sincerely

P/Bag 5543
OSHAKATI
01 APR 2022

TEOPOLINA HAMUTUMUA
CHIEF REGIONAL OFFICER

All official correspondences must be addressed to the Chief Regional Officer

Appendix 3. Recommendation for assistance

Dr. Valentine Y Katte
Head of Department
Civil and Mining Engineering
School of Engineering and Built Environment (SEBE)
University of Namibia, Eng. José Eduardo dos Santos Campus
P.O. Box 3624, Ongwediva, Namibia
vkatte@unam.na
Phone: +264 65 232 4017; Cell: +264815204937

23rd March, 2022

The Chairman

Oshana Regional Council

Oshakati

Dear Sir/Madame,

LETTER OF RECOMMENDATION FOR ASSISSTANCE TOWARDS RESEARCH

Ms. Salmi M.F Paulus (201055007) is an MSc student of the Department of Civil & Mining Engineering at the University of Namibia.

She is currently carrying out her research in the field of Water Resources Management and her interest is principally to carry out an assessment of personal water footprint in the Oshana Region.

We shall be grateful if you can give her the opportunity to gain access to sites documents or whatever she finds interesting that can be of help to her research, as well as interviews with the CEO and the personnel of the Regional Council.

I shall look forward to your assistance in this respect, and use this opportunity to appreciate your contribution to the training and skilling of our students.

Yours sincerely,

Dr. Valentine Y Katte

School of Engineering & The Built Environment
Department of Civil Mining & Engineering
2022 -03- 23
Office of the Head of Department

Appendix 4. Informed consent for qualitative studies

INFORMED CONSENT FOR QUALITATIVE STUDIES

Informed Consent for community members who will be invited to participate in the water foot research titled "Assessment of Water Footprint for Better Water Management in Oshana Region, Namibia".

Name of Principal Investigator:	Salmi Paulus
Name of Sponsor:	Collaborative Research Centre (University of Bonn) & UNAM

This Informed Consent Form has two parts:

- **Information Sheet (this section, to share information about the study with you)**
- **Certificate of Consent (for signatures if you choose to participate)**

You will be given a copy of the full Informed Consent Form.

PART I: INFORMATION SHEET

Introduction

I am Salmi Paulus, pursuing a Master's degree at the University of Namibia. I am doing research on individual water footprint in Oshana region, which is the amount of water that you consume in your life daily. I am going to give you information and invite you to be part of this research. You do not have to decide today whether or not you will participate in the research. Before you decide, you can talk to anyone you feel comfortable with about the research. This consent form may contain words that you do not understand. Please ask me to stop as we go through the information and I will take time to explain. If you have questions later, you can ask them of me or of another researcher.

Purpose of the Research

The shortage of water is a serious concern not only in your community, but it affects the entire country. We want to find suitable ways in which water can be sustainably managed. We believe that you can help us by telling us how you use water in your daily activities. We want to identify the areas that consume more water to help with addressing the water scarcity problem in the community. We want to find out if water footprint is affected by socio economic background. We also want to understand the daily lifestyle by observing

the individual water consumption as this information might help us to give/propose better suggestions and recommendations concerning sustainability and management practices of water resources.

Type of Research Intervention

This research will involve your participation in a questionnaire that will take about 15-20 minutes of your time.

Participant Selection

You are being invited to take part in this research because we feel your participation is of very important to the research committee and your community at large. Understanding how you consume your water will help provide a solution to the water problems that we are currently facing in north-central Namibia.

Voluntary Participation

Your participation in this research is entirely voluntary. It is your personal decision that will not affect you in any way. You can choose to not take part or to withdraw at any time during the survey process without any explanation. If you choose not to participate all the services, you receive at this community will continue and nothing will change.

Procedures

We are asking you to help us learn more about water footprint in your community. We are inviting you to take part in this research project. If you accept, you will be asked to answer a few series of questions that will take between 15-20 minutes of your time. The research project consists of both open ended and closed ended questions. You may answer the questionnaire yourself, or it can be read to you and you can say out loud the answer you want me to write down. If you do not wish to answer any of the questions included in the survey, you may skip them and move on to the next question. The survey will be distributed by Salmi Paulus who will also collect the surveys. The information recorded is confidential, your name is not being included on the forms, only a number will identify you, and no one else except for Salmi Paulus who will have access to your survey.

Duration

The research takes place over 14 days. During that time, we will visit you one time only for the survey and the survey will take about 15-20 minutes. A follow up will only be done whenever there is missing/incomplete information in the survey.

Risks

We are asking you to share with us some confidential information, and you may feel uncomfortable talking about some of the topics. You do not have to answer any question or take part in the survey if you don't wish to do so, and that is also fine. You do not have to give us any reason for not responding to any question, or for refusing to take part in the survey.

Benefits

There are no personal benefits from this survey, however, your participation will benefit the community at large by informing the decision and lawmakers as well as water resources managers to make informed decisions on water resources in the northern part of Namibia.

Reimbursements

There are no remunerations for taking part in the survey. There are no costs involved in taking part in the survey.

Confidentiality

The research being done in the community may draw attention and if you participate you may be asked questions by other people in the community. We will not be sharing information about you to anyone outside of the research team. The information that we collect from this research project will be kept private. Any information about you will have a number on it instead of your name. Only the researchers will know what your number is and we will lock that information up with a lock and key. It will not be shared with or given to anyone except Salmi Paulus.

Sharing the Results

Nothing that you tell us today will be shared with anybody outside the research team, and nothing will be attributed to you by name. The knowledge that we get from this research will be shared with you and your community before it is made widely available to the public. Each participant will receive a summary of the results. There will also be small meetings in the community and these will be announced. Following the meetings, we will publish the results so that other interested people may learn from the research.

Right to Refuse or Withdraw

You have an alternative of not taking part in the survey. It is your personal decision that will not affect you in any way. You can choose to not take part or to withdraw at any time during the survey process without any explanation

Who to Contact

If you have any questions, you can ask me now or later. If you wish to ask questions later, you may contact me (Salmi Paulus, 0818620429, sallypaulus48@gmail.com

This research has been reviewed and approved by the relevant Ethics Review Committee at the University of Namibia, which is a committee whose task it is to make sure that

research participants are protected from harm. The committee reports to the University's Centre for Research Services. *You can contact* Salmi Paulus, 0818620429, sallypaulus48@gmail.com *or Centre for Research & Services at kmbulu@unam.na if you have any further queries about the study or* if *you have any concerns or complaints that have not been adequately addressed by the research team.*

You can ask me any questions about any part of the research study if you wish to. Do you have any questions?

PART II: CERTIFICATE OF CONSENT

(This section is mandatory.)

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked, have been answered to my satisfaction. I consent voluntarily to be a participant in this study

……. ……

Name of Participant (print) Signature of Participant

……

Date (day/month/year)

If illiterate

I have witnessed the accurate reading of the consent form to the potential participant, and the individual has had the opportunity to ask questions. I confirm that the individual has given consent freely.

…….

Name of Witness (print)

……

Signature of Witness

……

Date (day/month/year)

Statement by the Researcher/Person taking Consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands that the following will be done:

1. Information of the participant will not be given out and will be kept confidential.
2. Participation is entirely voluntary, and has the rights to refuse or withdraw from the survey.
3. Sharing of the research results with the participants will be done.

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this ICF has been provided to the participant.

……. ……

Name of Researcher/Person taking Consent (print) Signature

……

Date (day/month/year)

If Assisted by an Interpreter: Statement by Interpreter

I have accurately interpreted the information sheet to the potential participant in …… (insert name of target language), and to the best of my ability made sure that the participant understands that the following will be done:

1. Information of the participant will not be given out and will be kept confidential.
2. Participation is entirely voluntary, and has the rights to refuse or withdraw from the survey.
3. Sharing of the research results with the participants will be done.

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been interpreted correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

I declare that I will not divulge any information that I interpret during this research intervention to a third party outside this study.

……. ……

Name of Interpreter (print) Signature

……

Date (day/month/year)

Appendix 5. Questionnaire Surrey

Dear Participant

1. My name is Salmi Paulus student number 201055007. I am studying towards a Master's of Science in Water Resources Management degree at the University of Namibia (UNAM), and I am conducting a survey about personal water footprint in the Oshana Region.
2. I have selected you to participate in my study, because you belong to the group of people I want to include for my research. I would therefore like to invite you to complete this questionnaire.
3. The research I am conducting has been approved by the UNAM Research Ethics Committee. I would appreciate it very much if you would complete this questionnaire, and I would like to assure you of the following:
    a. You do not have to fill in this questionnaire if you do not want to.
    b. You can stop filling in the questionnaire and stop participating at any time if you want to, and there will be no negative consequences for you.
    c. Your participation is completely anonymous. This means that, even if I ask information that might identify you or if I know you, I am not allowed to make your identity known to anyone. When I report on my questionnaires' data and results, I will not mention any personal information about participants that might identify them.

d. All completed questionnaires and data will be stored in a safe and secure place, and only authorised University officials, my supervisor and I will have access to it. After five years, all the questionnaires and data will be destroyed in an environmentally friendly way.

4. If you have any questions about this questionnaire, or if you do not understand anything, please feel free to ask me, and I will be happy to explain it to you.
5. If you want to know more about the research I am doing, please feel free to ask me, and I will be happy to tell you more.
6. It should take about 15-20 minutes for you to complete the questionnaire.
7. You can reach me on my cell phone at 081 86 20429, or send an e-mail to sallypaulus48@gmail.com.
8. If you want more information about the study *you can contact me (Salmi Paulus 0818620429) or Centre for Research & Services at* kmbulu@unam.na if *you have any further queries about the study or* **if** *you have any concerns or complaints that have not been adequately addressed by the research team.*
9. Thank you very much for your willingness to participate in this research!

Please detach this page and keep it.

Please turn over to start filling in the questionnaire.

PERSONAL WATER FOOTPRINT

QUESTIONNAIRE

INTRODUCTION

Thank you for agreeing to help the MSc. Student in Water Resources Management learn about your individual water footprint. The aim is to help the student assess the personal water footprint in the Oshana Region. Your answers are completely anonymous and cannot be linked to you in any way that can identify you.

Please answer the following questions by putting an "X" in the box for the answer or answers that come closest to your opinion, or by writing your answer in your own words in the spaces provided.

For example: If you were asked to indicate your gender and you are female, you should answer the question as follows:

Question: What is your gender?

[ ] Male

[x] Female

Please be kind to not leave any question unanswered. If there are any questions that require figures you cannot answer, please give a rough estimate that is closest to your answer.

If you need to change an answer, please fill in the box you marked at first and want to change. So to change "Female" to "Male" mark it as shown below:

[**x**] Male

[ ] Female

SECTION 1: SOCIO-ECONOMIC STATUS

1. Gender: _____ 2. Age: _____

3. What is the highest level of education you have completed?

- ☐ Never attended formal education
- ☐ 12th grade or less
- ☐ High school graduate
- ☐ Technical school training
- ☐ College graduate
- ☐ Graduate school degree: Master's or Doctorate degree (MD, PhD, JD)

4. What best corresponds below to your current Occupation?

- ☐ Working full time
- ☐ Working part time
- ☐ Not working and not looking for work
- ☐ Unemployed and looking for work
- ☐ Disabled or retired
- ☐ Currently in school

5. Do you have other resources to support your family? Yes ☐ No ☐

If you answered "Yes" to the above question; what resources do you use?

- ☐ Drought relieve food assistance
- ☐ Pension fund
- ☐ Child support
- ☐ Selling kapana/ street vending
- ☐ Disability income
- ☐ Other

6. What is your gross yearly income? (Only that part of income which is consumed by you). If you don't know your exact income, please estimate.

- ☐ Less than N$ 100 000
- ☐ N$ 100 000 – 150 000
- ☐ N$ 150 000 – 200 000
- ☐ N$ 200 000 – 250 000
- ☐ N$ 250 000 – 300 000
- ☐ N$ 300 000 – 350 000
- ☐ N$350 000 – 400 000
- ☐ N$400 000 – 450 000
- ☐ N$450 000 – 500 000
- ☐ More than N$ 500 000
- ☐ Chose not to answer

SECTION 2: FOOD CONSUMPTION

1. How much cereal products do you eat per week? (wheat, rice, maize, etc.)

_____kg/week

2. How much meat products do you eat per week?

_____kg/week

3. How much dairy products do you eat per week?

_____kg/week

4. How many eggs do you eat per week?

_____number/week

5. How do you prefer to take your food?

Fat content:

- ☐ With Average fat
- ☐ With Low Fat
- ☐ With High fat

6. How is your sugar and sweets consumption?

Sugar consumption:

☐ Average

☐ Low

☐ High

7. How much vegetables do you eat per week?

_____kg/week

8. How much fruits do you eat per week?

_____kg/week

9. How much starchy roots (potatoes, cassava) do you eat per week?

_____ kg/week

10. How many cups of coffee do you take per day?

_____Cup/day

11. How many cups of tea do you take per day?

_____Cup/day

SECTION 3: DOMESTIC WATER USE - INDOORS

1. How many showers do you take each day?

_____Number/day

2. What is the average length of each shower?

_____Minute/shower

3. Do your showers have standard or low-flow showerheads?

☐ Standard shower head

☐ Low flow shower head

4. How many baths do you have each week?

_____Number/week

5. How many times per day do you brush your teeth, shave or wash your hand?

_____Number/day

6. Do you leave the tap running when brushing your teeth and shaving?

☐ Yes

☐ No

7. How many loads of laundry do you do in an average week?

_____ Times/week

8. Do you have a dual flush toilet?

☐ Yes

☐ No

☐ No flushing. Use eco-toilet.

9. If you wash your dishes by hand how many times are dishes washed each day?

_____Number/ day

10. How long does the water run during each wash?

_____ Minute/wash

11. If you have a dish washer, how many times is it used each week?

_____Number/week

SECTION 4: DOMESTIC WATER USE – OUTDOORS

1. How many times per week do you wash your car?

_____ Number/week

2. How many times do you water your garden each week?

_____Number/week

3. How long do you water your garden each time?

_____ Minute/watering

4. How long per week do you spend rinsing equipment, driveways, or sidewalks each week?

_____Minute/week

5. If you have a swimming pool what is its capacity?

_____cubic meter

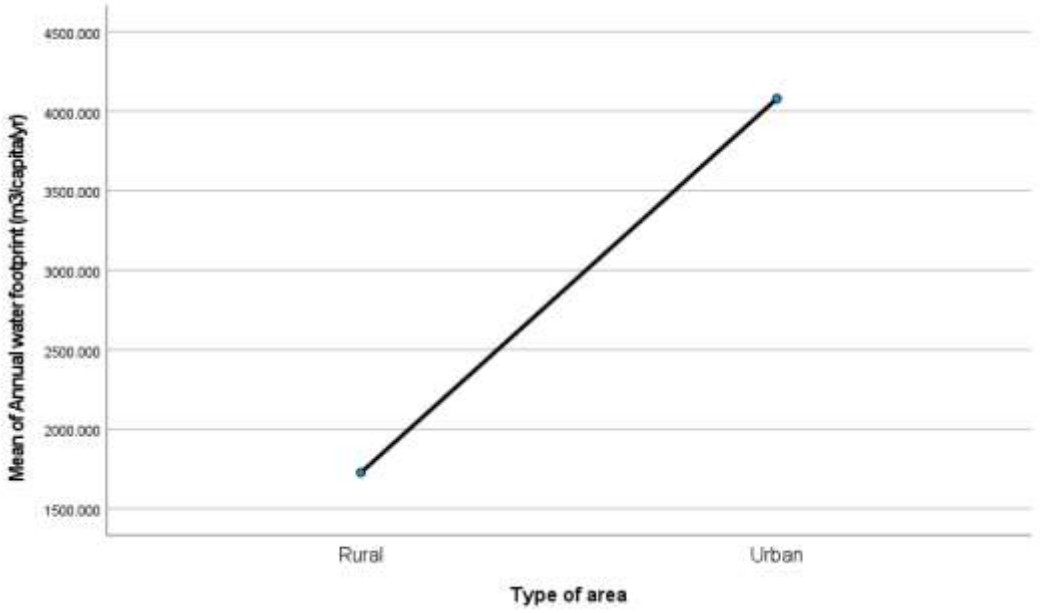
6. How many times per year do you empty your swimming pool?

_____Number/year

Appendix 6. ANOVA Descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Type of area	6	1	2	1.50	.516
Annual water footprint	16	1094	6325	2902.84	1547.508
Valid N (listwise)	16				

Appendix 7. Mean Plots



Means plot indicating the mean variation between constituencies