2024 Scienceline Publication

Journal of Civil Engineering and Urbanism

Volume 14, Issue 3S: 334-338; September 15, 2024

ISSN-2252-0430

DOI: https://dx.doi.org/10.54203/jceu.2024.37

Estimation of Water Demand for the Rural Population in the Angolan Part of the Iishana System

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RESEARCH ARTICLE
PII: S225204302400037-14
Received: June 25, 2024
Revised: September 02, 2024
Accepted: September 05, 2024

ABSTRACT

The Iishana is a shallow, low-slope channel system located in the Cuvelai basin (Southern Angola and Northern Namibia), characterised by drought and flood cycles due to erratic climate variability. The knowledge gap regarding the actual water needs in the area, the number of residents within the system, the seasonal influence of cattle migration, and poor socio-economic conditions, make the population even more vulnerable to droughts. The main objective of this study is to estimate the water demand by the rural population on the Angolan side of the Iishana system, attempting to fill the knowledge gap. To reach the demand estimates, a mathematical procedure within a GIS environment was used, in QGIS 3.32.2 software, relating population gridded and meteorological data to make the necessary calculations. In 2023, it estimated consumption for intake and personal hygiene of 4.7 Mm^3, 6.3 Mm^3 for 2033, 8.4 Mm^3 for 2043 and 11.3 Mm^3/year for 2053. In recent years there have been rainfall records throughout the Iishana system, at an average of 518 mm/annum, but high temperatures accelerate water evaporation. Due to the topographical conditions, the waters are drained by gravity to the south of the basin (Republic of Namibia), causing a greater shortage in the dry season on the Angolan side, the study targets the estimation of water demand and the concept of rainwater harvest and sustainable water infrastructure to supply safe drinking water to equalise water demand and reduce vulnerability to climate change. These early findings may provide a basis for developing sustainable water infrastructure and use plans to improve the livelihoods of the resident population within the basin.

Keywords: Water demand, Water supply, Iishana system, Cuvelai Basin, Water infrastructure.

INTRODUCTION

Water resources are finite, and their demand continues to grow alongside the rising population. Simultaneously, the increasing frequency and intensity of floods and droughts place significant pressure on livelihoods (Seckler, 2000). Effectively evaluating the water requirements of both the population and the environment within the Cuvelai Hydrographic Basin, while ensuring adequate protection against these natural events, presents a considerable challenge. The most active watercourses are confined to the Iishana area. The water in the Iishana Canal area is saline, reflecting the high rates of water evaporation in all the watercourses (Mendelsohn & Weber, 2011).

Once the main courses are reduced and then stop, large areas of water remain in the channels and gradually dry out, leaving salts that accumulate in the substrate, it isn't easy to access water for human and animal consumption residents along the Cuvelai basin.

MATERIALS AND METHODS

Study area

Figure 1 illustrates the Iishana System, a transboundary wetland shared by Angola and Namibia, spanning approximately 18,370 km². In Angola, a significant portion of the Iishana System lies within the municipalities of Cuanhama, Cuvelai, and Namacunde, situated in the province of Cunene. This area covers roughly 8,711 km², of which 651 km² are inhabited, housing an estimated population of 521,763 individuals, according to (Bondarenko M., 2020), with the coordinates: Northen -16°.47'85N''-15°.26'34 E'', South -

To cite this paper: Chiweyengue AM, Serrão Pires EE, and Afis BO (2024). Estimation of Water Demand for the Rural Population in the Angolan Part of the Iishana System. *J. Civil Eng. Urban.*, 14 (3S): 334-338. DOI: https://dx.doi.org/10.54203/jceu.2024.37

17°.37’12N’’-15°.25’58E’’ West -16°.94’79N’’-15°.66’19E’’ East -17°.01’93N’’-14.78’99E’’ Majority of the population lives along the drainage lines of the Iishanas in the southwest, with a mixture of sandy and clay rhinestones more suitable for agriculture than the sandy lands that cover most of the areas to the east and north of the Lishana. Many people also live around the lowlands to the southwest and along small rivers to the north, between the towns of Evale, Mupa and Cuvelai (Helge Denker et al., 2014).

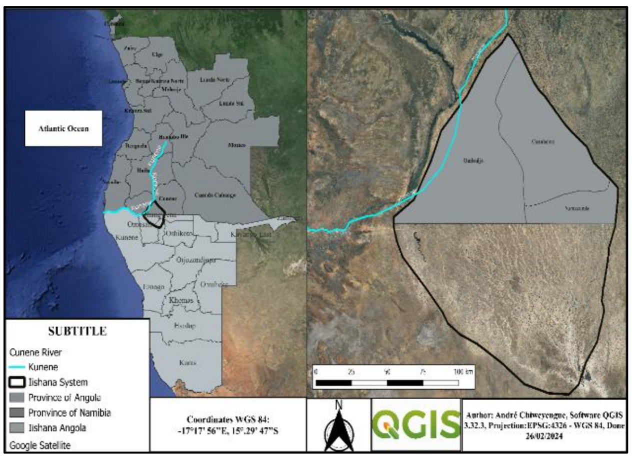

Figure 1. The Angolan part of the Iishana system.

Water demand

The unsustainable and excessive exploitation of natural resources has hindered societal growth over a short period and poses bleak prospects for the future. To address this issue, new strategies must be established that prioritize sustainable development and set clear limits on the use of natural assets, ensuring a balanced approach between utilization and environmental protection (Amaral, 2000). Water demand refers to the volume of water required to supply production and distribution systems, accounting for consumer needs, as well as losses and waste within the system (EEA, 1999).

Estimation of water consumption

The per capita water consumption of a city with a regularly functioning water supply system is determined by dividing the total volume of water distributed annually by the number of inhabitants served (Yassuda et al., 1978). This calculation is expressed mathematically in Eq. 1 and is measured in litres per inhabitant per day (L/person/day).

$$\text{Water consumption} = \frac{V}{365\,P} \qquad (1)$$

where V is the annual available volume; P is the population

Estimating water consumption in urban public supply systems presents significant challenges due to unreliable data from systematically conducted research. The volume of water needed to supply the basic needs of man and his socioeconomic activities has varied according to the customs and ways of life imposed by the technological transformations that have occurred in recent decades. Netto (1991) Various factors are linked to water consumption patterns, including: (i) Population Growth: Studies reveal that an increase in population typically results in higher per capita water consumption. This rise is largely due to expanded commercial and industrial activities, along with an elevated likelihood of distribution network losses: (ii) Urban Characteristics: The type of urban area significantly impacts water usage levels. For example, water consumption per capita in a tourist town differs from that in an industrial city, with the latter often having higher average consumption and greater water-related costs; (iii) Climate Conditions: Regions with warmer climates generally exhibit higher water consumption. These influences contribute to variations in daily per capita water consumption, which tend to fluctuate based on specific local factors.

Population estimation

Using the WorldPop 2020 dataset to determine the population number, QGIS software processes this data through Zonal Statistics. This algorithm calculates statistical values for a raster layer based on the features of an overlapping polygon vector layer. By applying this method, it aggregates data, such as population estimates, within the defined zones of the polygon layer, providing valuable insights into the spatial distribution of the population.

Analysis of climate data

For the analysis of the climatic data, the data provided by the ERA5 website according to (Hersbach et al., 2023), and data from the last 32 years (1992-2023) were downloaded, analyzed and processed in Python and by QGIS version 3.32.2, interpolated in the Inverse Distance Weighted (IDW) interpolation, it generates a point vector layer. Sample points are weighted during interpolation such that the influence of one point relative to the other declines with the distance from the unknown point to be created.

Calculation of water demand

CSIR (2005) states that water demand is usually based on historical consumption. Where water consumption records are not available, present consumption per capita can be estimated by administering the questionnaire. Estimating water demand requires the following algorithms: (i) Determine the size of the population in the area; (ii) Multiply the population by the average daily water usage per person; (iii) incorporate the peak demand factor to cater for fluctuations in demand and potential water waste

RESULTS AND DISCUSSION

Climate Data Precipitation

The analysis of 31 years of data (1992-2023) gives a descriptive minimum average rainfall of 257.2 mm and a maximum of 517.6 mm. Rainfall in the north is approximately twice that of the southern region of the Basin (Figure 2). These usually occur during the wet season, specifically between November and April. This often results in large-volume storms of high frequency at short intervals. Due to the very flat nature of the terrain, the canals flow from north to south, from the southern Angolan plateau to the Etosha pan. Based on the livelihood mode (pastoralism, agriculture, and hunting) of the population residing in the Iishana system, these averages are considered below the threshold of water demand needed for survival. The Basin has a long history of floods and droughts due to the irregularity of rainfall over the last 31 years.

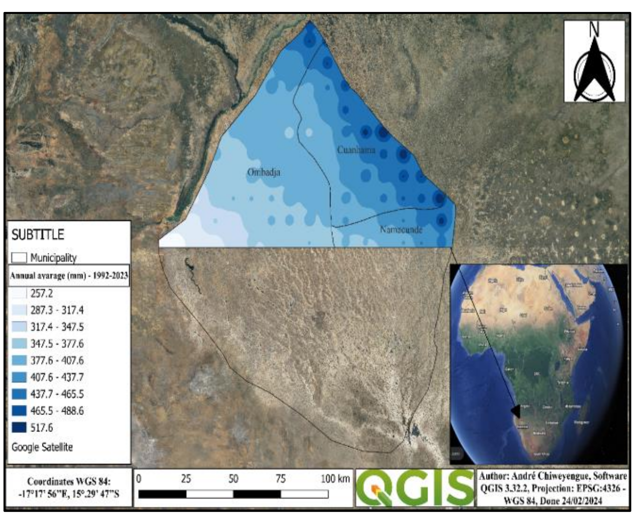

Figure 2. Average annual rainfall (1992-2023) of the Iishana system in mm

Temperature

In the last 31 years (1992-2023), an average temperature of 23° had been observed (Figure 3). The temperatures are highest in the southernmost regions of the basin. Consequently, temperature is one of the major factors that affect the amount of water consumed in the Iishana system of the Cuvelai basin. Therefore, on warmer days, it is common for water consumption to increase, for domestic activities and irrigation of plants. Climate change has an impact on water resources, affecting the water cycle. This is due to changes in precipitation patterns and the role of temperature as it accelerates the evaporation process in the Iishana system.

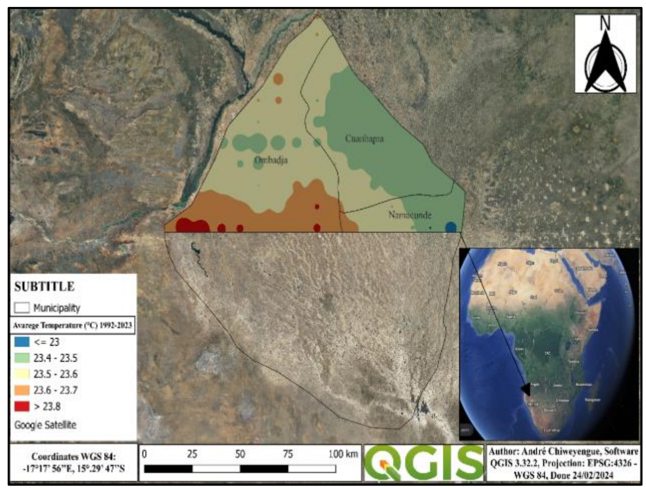

Figure 3. Average annual temperature (1992-2023)

Population Forecast

DATA:

Inhabited area: 651 km^2

Rural Population: 426273 inhabitants.

Population growth of 3 % per/year (INE, 2016)

Population projection 2033 (Eq.2)

$$P_{projection} = P_{base\ year}\left(1 + \frac{Annual\ Growth\ Rate\ (\%)}{100}\right)^{n} \quad (2)$$

Where $P_{base\ year}$ is the base year population (2023)

$$P_{2033} = 426273\left(1 + \frac{3\%}{100}\right)^{10} = 572875 \text{ inhabitants.}$$

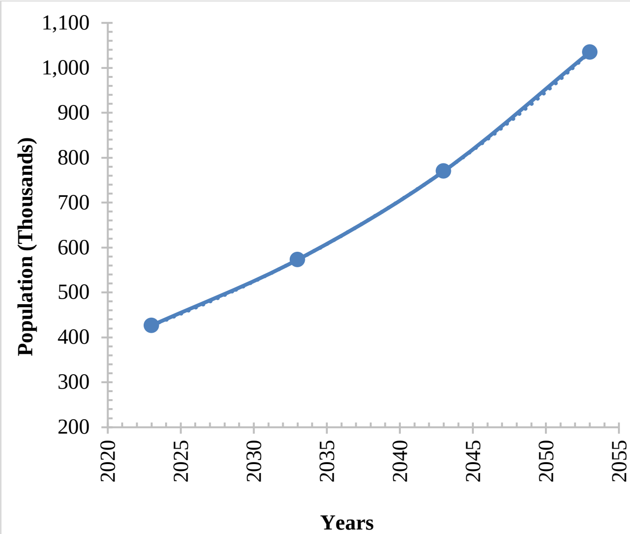

Figure 4. Probable future population (world pop 2020)

Currently, the population of the rural area is 426,273 inhabitants. Figure 4 displays the population forecast projection for the next three decades. Hence, the population of 572,575, 769,896 and 1,034,676 inhabitants for 2033, 2043 and 2053 respectively. This poses a threat to the available water supply in the future. Consequently, population growth has a range of effects on water consumption, from residential demand to pressure on water resources and the need for sustainable management to address these challenges. It is essential to adopt sustainable strategies to ensure access to water for future generations.

Water demand

According to the (MINEA, 2024), the per capita demand both for intake and personal hygiene, for the population of rural areas should be 30L/person/day. It can be calculated by below formula (Eq.3):

$$Water\ Demand\ (per\ day) = \left(\frac{\text{L/person/day} \times\ P}{1000}\right) \quad (3)$$

$$Water\ Demand\ (per\ day) = \left(\frac{30l/d \times 426273}{1000}\right) = 12{,}788.19 m^3/day$$

Annual water demand becomes:

$$f_p \times (12{,}788.19 m^3/day)\ \times 365 = 4667689.35\ m^3/year\ = \left(\frac{4667689}{1000000}\right) = 4.7 Mm^3/year$$

f_p = 1.1 is the peak demand factor (MINEA, 2024)

From Figure 5, the year 2023 yielded a consumption for intake and personal hygiene amounting to 4.7 Mm^3. The forecasted consumption for the years 2033, 2043 and 2053 are 6.3 Mm^3, 8.4 Mm^3 and 11.3 Mm^3/year respectively. A significant increase in future water consumption, with the impacts of climate change, can cause an increase in water scarcity in the Iishana system, which represents a great challenge for climate adaptation. The increase in water demand can have significant consequences across various domains. This includes pressure on existing water resources, competition among different sectors and users, environmental degradation, depletion of groundwater, impacts on agriculture, and economic costs. In summary, the growth in water needs can trigger complex challenges that demand careful and sustainable water resource management to mitigate its adverse effects.

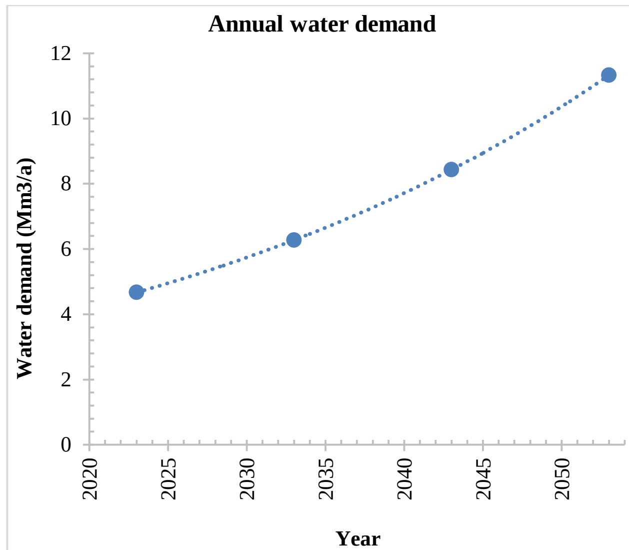

Figure 5. Projection of annual water demand

CONCLUSION AND RECOMMENDATION

The rural population of the Iishana system faces challenges related to climate change, in the last 31 years there have been records of rainfall throughout the Iishana system, but high temperatures accelerate the evaporation of water. Due to the topographical conditions, the waters are drained by gravity to the south of the basin, (Republic of Namibia), causing a greater shortage in the dry season on the Angolan side. With the population increasing, water scarcity is a significant concern in that region, to mitigate this impact and ensure a conscientious use of this valuable resource. It is recommended to reuse rainwater, retain water from the Iishna, and build water points to ensure access to drinking water (boreholes for the population and chimpaca for the animals) and reduce vulnerability to climate change.

DECLARATIONS

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Acknowledgements

The authors would like to express their gratitude to SASSCAL 2.0 for its financial support. Appreciation is also extended to ISPTundavala and the University of Namibia for fostering an environment conducive to conducting this research.

Authors' contribution

First Author analysed the data obtained and wrote the manuscript. The second downloaded the climate data, the third and fourth Authors supervised, revised and approved the manuscript.

Competing interests

The authors declare no competing interests in this research and publication.

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