Analysis of Current and Future Water Demand Scenario in Yejube Town, Ethiopia

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Abstract
Yejube is one of the rapidly developing towns in Ethiopia. Difficulties of acceptable water supplies and reduction of non-revenue water remains one of the main challenges facing Yejube water supply system. This study is concentration on the analysis of water demand scenario and future water demand forecasting of for Yejube town. A mixed cross-sectional research method was implemented to analyzed the past and future water demand of the town. The outcome of this study found that the municipal average daily water consumption per capita was 14.3l/c/day and 16l/c/day respectively in 2017 and 2018. The water supply coverage of the town is low when we compare the regional and international standards. Water production and demand are unbalanced, due to continuous interruption of the water supply system inhabitants are facing water related problems. And also, 20.38% and 24% of the water production lost in the distribution system before reaching to the end customers. The population of the town in 2040 expected to reach 24807 with an average daily per capita water consumption of 36.7l/day. Generally, delivery of hygienic Water Supply is one of the key influencing factors that significantly subsidize to the socioeconomic renovation of a country by enlightening the health thereby increasing life standard and economic productivity of the society. Therefore, accurate forecast of future water demand plays a crucial role in optimizing the need for potable water resources and effective water allocation among competing users.
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1. INTRODUCTION

1.1. Background of the Study

Water is one of the vital necessity or the need for human being and for all living things (Temesgen M. et al., 2016; Birhan A., 2016). The access of enhanced clean water supply is one of the major factors that greatly contribute to the socio-economic transfer of once county by improving the life style and health thereby escalating life standard and economic productivity of the society (Benyam B., 2016). In the world fresh water that has been used for household purpose is not more than 3% of the natural available water resource on the earth (WHO/UNICEF, 2017).This is very small in amount of wholesome water compared with the saline water body exist on the earth. As a result, millions of people in the world are facing a shortage of adequate safe drinking water in terms of quantity and quality. WHO/UNICEF Joint Monitoring Program conferring that, in 2015, 91% of the population around the globe used drinking water from improved sources (58% from a piped connection in their home, yard, and 33% from other enhanced sources), 663 million people leaving lacking access for an enhanced water source (WHO/UNICEF, 2017). The majority of the developing countries in Africa and Asia are greatly affected by the problems of access to clean and safe potable drinking water supply (UN, 2012). However, most of the developing countries like Ethiopia have still unable to obtain adequate potable water and have low potable drinking water supply coverage that results citizens to be suffered from shortage of water (Chalchisa M., 2017; Lema K.,2018; Rata F., 2018).

Ethiopia is very well known by its massive water resource potential all of which is generated in its own tertiary and it is still known the water tower of Africa (Gelamo A., 2014; Makonnen A., 2014; Birhan A., 2016; Kumar A. & Getu T. 2018; Tariku N., 2018). But, access of potable drinking water supply coverage in Ethiopia is amongst the lowest in sub-Saharan Africa as well as the entire world (57.3% in 2015), while access has increased substantially with funding from external aid much fill reminds to be done to achieve the MDG and SDG (GTP-I and GTP-II) of halving the share of people without access to water and sanitation. However, Ethiopian government is working to address the problem of safe access of drinking water in different towns of the country (Abraham B. & Mushir A. 2015; Lema K., 2018; Rata F. 2018). In order to address the need of water demand a long distant piped water supply networks to the city is emerging as a measure where the nearby water sources are scarce, polluted or inadequate to satisfy the high level of demand due to the change of living standard and increase in population in the town (Kumar A. &_Abdirasak H. 2018; Kumar A. & Getu T. 2018; Marieke A. et al. 2018; Tariku N. 2018).

Most of the decisions in urban planning and sustainable development programs are extremely dependent on the accessibility of water resources and forecasting future water demand. Forecasting water demand can be accomplished by formulating suitable mathematical water demand model based on the different factors (variables) that distress water consumption ((Brentan B. M. et al., 2017; Mandefro and Habtamu, 2017). Reorganization of the most imperative and momentous variable among these entrant variables is fundamental in the development of projecting model, as the accurateness of the model be subject to choose of suitable variable (Thewodros G. et al., 2013; Steven B. et al., 2015). Water demand forecasting can be performed either short-term or long-term forecast depending on its purpose and their modeling techniques. Short-term forecast is commonly required for O&M of existing water supply scheme within a limited days or weeks (Di Tian et al., 2016). Long-term forecast accounts different factors (variables) that encouragement in the planning, expansion, and design of new infrastructure as well as identification of effective measure to meet water demand with quantity and quality standards(Hejazi M. et al., 2014; Qin T. L. et al, 2014; Kokkinos K., et al., 2016; Gedefaw et al., 2018). It is also important for evaluating effectiveness of management measures and developing guidelines and strategies such as water tariff setting (Brentan B. M. et al., 2017). In general, water demand forecasts for the design, planning and implementation of the water distribution system are very imperative in modern societies in order to ensure water availability and meet the need for water design for a sustainable economic water supply scheme (David L. et al., 2016).

A well-organized water supply distribution system should provide water for domestic, commercial, public, industrial and livestock and other uses in relations to quantity coverage, consistency and reasonable quality considering the current and upcoming certainties of the area (Birhan A., 2016; Mulatu B., 2016; Lema K., 2018; Nega A., 2018; Tariku N., 2018; Rata F., 2018). This paper intends to assess urban water supply production and demand coverage in Yejube town. Yejube town has been facing a lot of problems related with potable drinking water supply inadequate or sufficient quantity and quality. Even if the modern water supply system of the town was installed since in 1977 and expanded its services from time to time to meet the need of the people by developing a number of boreholes and artesian wells, but still the demand is not satisfied and a number of peoples do not have access to sufficient amount of clean and safe drinking water. The overall aim of the study is to analysis demand scenario in the past and for the future and perform water demand forecasting using simple coefficient approach. Generally, the study will focus on assessing the potable drinking water supply system current and future demand scenario in Yejube town.

1.2. Objective of the Study

The overall aim of this study was to assess the degree, exposure and future water demand scenario of urban water supply system in Yejube town i.e. analysis and forecasting urban water demand in the study area.

The specific objectives of the research were as follow:

1) To evaluate and portray the source, type, status and coverage of water supply in the area,
2) To assess the functionality and service level of the existing water supply system in the town,
3) To evaluate the water production, consumption and loss in the water supply system of the town
4) To forecast future water demand scenario in the area
5) Recommend the way forward for the sustainability of water supply scheme in the study area,

2. MATERIAL AND METHODOLOGY

2.1. Description of Study Area

The study area, Yejube town, is located in Baso Liben Woreda, East Gojjam Zone of Amhara National Regional State, at about a distance of 276 km far from Bahir Dar and about 26 km from Debre Markos (Zonal capital) of which 10 km distance is asphalt road and the remain 16 km is well aligned gravel road along to south direction from Addis Ababa road (Aklilu G., 2009). The geographical location is at 1122035mN and 362607m E and elevation of 2311.11a.m.s.l with flat topography (AWRDB, 2016).

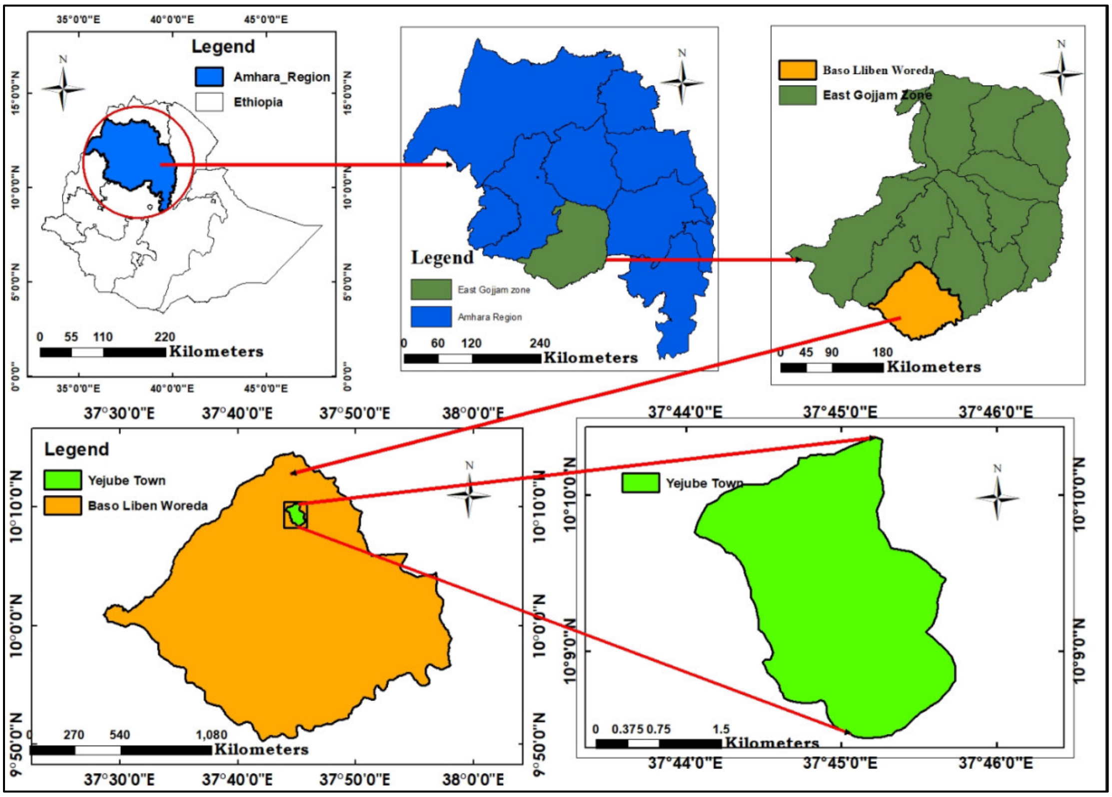

Figure 2.1 : Location Map of Yejube Town

2.2. Methodology

2.2.1. Data Type and Sources

A combination of both quantitative and qualitative data was generated from sources. The data were gathered from the Woreda Water Resource Development Office, Yejube Town Water and Sanitation Service Authority and field visit. To make this research work more valid and worthy, relevant secondary sources relevant to the study were consulted in an effort to supplement the primary data. The main sources of secondary data for this study were the national water supply access plan (GTP-I and GTP-II), urban water supply policy and guideline, official statistics and reports available in water projects implementing agencies ' offices. In addition, various written documents-both published and unpublished-books, CSA, government, non-governmental documents, journals, and research works on the subject under consideration; national policy and strategy were reviewed to complement the study and also examine the current and future urban water supply scenario in the study area.

2.2.2. Data Collection

The data collected mainly on Primary and secondary information. The information used includes population, water production, water consumption, water loss, general layout, existing water supply system and photogrammetric image. Water demand projection continually requires one or more possible descriptive variables, and frequently needs data for water use itself and population serviced. A descriptive variable is one which has been detected to describe, the entire or in fragment, historical variation in water demand. The most commonly cast-off descriptive variable is the provision area inhabitants, even though many other demographic, socio-economic, climatic, and technologic variables can be considered. One of the simplest available forecasting approaches requires knowledge of past collective water use, past population levels, and expected future population levels. The population data for the study area was collected from CSA and Baso Liben Woreda economic development office**.** The monthly water production, loss and consumption data in the last two years were collected from YTWSSA. The general layout of existing water supply distribution system components such as number of public taps with the current status, and number of service Reservoir with their storage capacity and status data collected from the YTWSSA and field observation.

2.2.3. Data Analysis and Reliability

The quantitative data which shows the population, water use, water production and water loss in percentage as well as the numerical data were analyzed interpreted in tabular and graphical forms. Qualitative data that shows the trend, status, challenges and perspectives of the urban water supply and demand scenario was aggregated, interpreted and explained with the support of the quantitative data analysis. The analysis of future water demand scenario is based on the FDRE MoWR Water Supply Design Guideline 2006 and World Bank cost effective design guideline. The difficulties regarding to future water demand estimations are the data required is not always available, and often published figures for past water uses are unreliable. This has arisen because there is no uniformity in the classification of water uses in the study area; estimation of the amount of water used is still the major way to obtain water use data rather than that recorded by water-meters. Even when water-meters are installed, water use data can be recorded irregularly, and cannot be aggregated. Due to the lake of available data and unreliable past records, simple coefficient forecast method was used to forecast and analysis the future water demand and water loss in the area. Generally, both qualitative and quantitative analysis techniques were used for data analysis and interpretation.

3. RESULT AND DISCUSSION

3.1. Existing Water Supply Coverage in the Town

During the MDG Ethiopian Water Supply access coverage increased from 14% to 57% (43% point increase). Provide urban water supply access with GTP-2 minimum service level of 100l/c/day for category-1, 80 l/c/day for category-2, 50 l/c/day for category-3, 40 l/c/day for category-4, up to the premises distance of 250m and 20-25 l/c/day for category-5 and category-6 towns within a distance of 500m with piped system for 75% of the urban Population.

3.1.1. Water Production

The annual water production rate in 2017 and 2018 was 68,916m^3 (32.78%) and 89,928.7m^3 (42.77%) respectively. But, the water production capacity of the borehole in the area is 20l/s (210240m^3/year within 8-hour pumping) so the water produced in the last two year was below this figure. The water production of the town shows an increasing trend from year to year but there is variation in monthly water production. As shown in the Table 3.1 below the lowest water production in 2017 was recorded in April and May with monthly production of 5122m^3 and 5185m^3 respectively and highest production in August (6316m^3). In 2018 the water production shows increasing progress in all months with lowest and highest production rate of 6560.7m^{3}8140.1m^3 in February and July respectively. Generally, the water production shows seasonal variation with highest production in Summer (Kiremt) and lowest production in Winter (Bega) and Spring (Tseday).

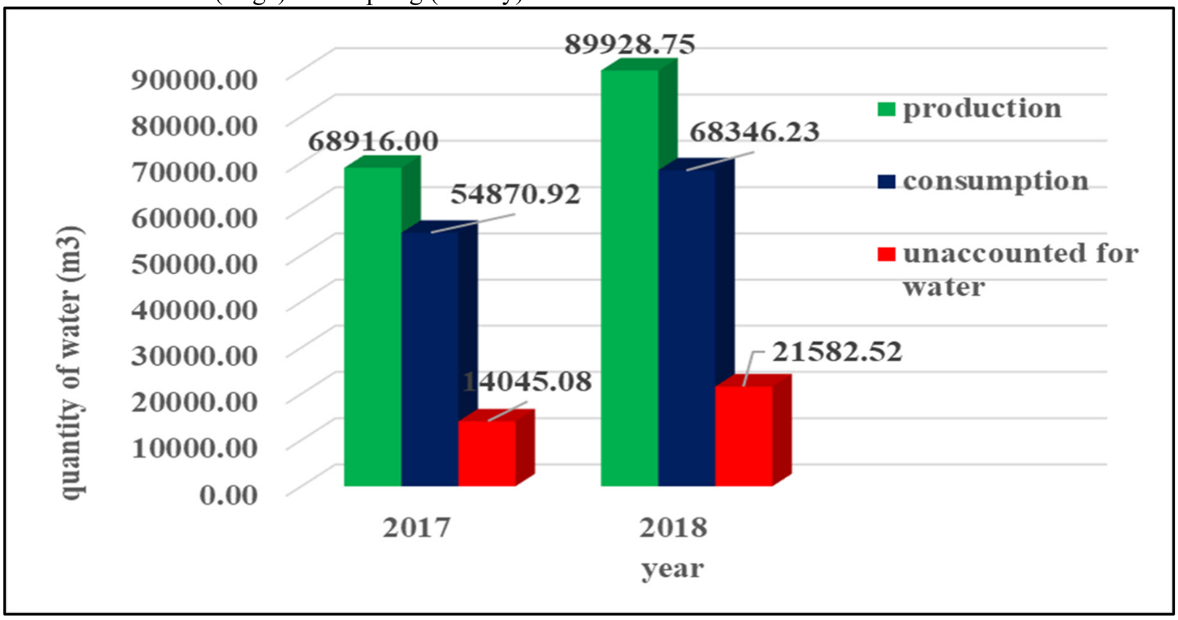

Figure 3.1: Water production, consumption and unaccounted for water in 2017 and 2018

3.1.2. Water consumption

As shown in the Table 3.1 below the lowest water consumption rate in 2017 was recorded in May with monthly production of 4252.8m^3 and highest value in August (4849.0m^3). In 2018 like that of the water production, the water consumption shows increasing trend in all months with lowest and highest production rate of 5004.6m^{3}and 6173.8m^3 in March and August respectively. Generally, the water consumption shows seasonal variation with highest in Summer (Kiremt) and lowest in Winter (Bega). The water consumption of the town shows an increasing trend from year to year an average monthly consumption of 4572.575m^3 and 5695.517m^3 in 2017 and 2018 respectively.

3.1.3. Non-Revenue Water

The water loss analysis of Yejube town were assessed in aggregated form in numerical as well as percentage of the Non-revenue water which was obtained from the total water production and water consumption. According to the data obtained from Yejube town water and sanitation service authority, the water loss in the town can be identified using the water production and water consumption (billed water volume). The monthly non-revenue water can be calculated and tabulated in Table 3.1. using the following formula.

$$\text{NRW= WP- BAC} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.1)}$$

Where: BAC-billed authorized consumption, NRW-Non-revenue water and WP-Water production

Unaccounted-for-water loss additionally articulated as a ratio and, has normally assessed as the difference of net water production delivered to the network and billed consumption use divided by net production and multiplied by 100 (EPA, 2010).

$$\text{UFW} = \left(\frac{\text{WP}-\text{BAC}}{\text{WP}}\right)\times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.2)}$$

Table 3.1: Total monthly water production, consumption and loss in 2017 and 2018

Month	2017			2018		
	Production	**Consumption**	**Loss**	**Production**	**Consumption**	**Loss**
July	5443	4487.9	955.1	6857.5	5303.1	1554.4
Aug.	5402	4435.2	966.8	6560.7	5197.3	1363.4
Sept.	5450	4404.6	1045.4	6692.8	5004.6	1688.2
Oct.	5122	4312.3	809.7	6850.9	5307.5	1543.3
Nov.	5185	4252.8	932.2	7808.6	5804.7	2003.9
Dec.	5613	4483.2	1129.8	8011.7	6078.7	1933
Jan.	6113	4571	1542	8140.1	6148.6	1991.5
Feb.	6512	4849	1663	8108.7	6173.8	1934.9
Mar.	6316	4752.2	1563.8	7943.2	5949.6	1993.7
Apr.	6210	4958.2	1251.8	7807.9	5926.1	1881.9
May.	5832	4707.6	1124.4	7620.9	5783.8	1837.1
Jun.	5718	4656.8	1061.2	7525.7	5668.5	1857.2
Total	68916	54870.9	14045.1	89928.7	68346.2	21582.5

3.2. Analysis of Water Supply Coverage and Scenarios

3.2.1. Average per capita demand coverage

The water supply coverage of the city has been evaluated based on the average per capita consumption. The average water consumption per capita was derived from the city's annual consumption, which was aggregated from the individual water meter and the public tap. Thus, the annual water consumption data was converted to average daily per capita consumption using the population data of the town.

$$\textbf{PerCapitaConsumption(l/c/day)} = \frac{\textbf{annual consumption}(\mathbf{m^3})\times\frac{\mathbf{1000l}}{\mathbf{m3}}}{\textbf{Total population}\times\textbf{365days}} \ldots\ldots \text{(3.3)}$$

Using this formula, the aggregated per capita water consumption can be calculated in the year 2017 and 2018 and tabulated in the following table.

$$\text{PerCapitaConsumption(l/c/day)(2017)} = \frac{54870(\text{m}^3)\times\frac{1000\text{l}}{\text{m3}}}{10641\times 365\text{days}}$$

$$=14.13\text{l/c/day}$$

$$\text{PerCapitaConsumption(l/c/day)(2018)} = \frac{68406(\text{m}^3)\times\frac{1000\text{l}}{\text{m3}}}{11219\times 365\text{days}}$$

$$=15.99\text{l/c/day}$$

Table 3.2: Per capita water consumption of the town in 2017 and 2018

year	Annual Consumption (m^3)	Per capita Consumption (m^3/year)	Per capita Consumption (l/day)	Domestic Demand (l/day)	Non-domestic demand (l/day)
2017	54870	5.1565	14.13	9.89	4.24
2018	68406	6.097	15.99	11.2	4.79

As shown in the table above the aggregated average per capita water consumption (domestic and non-domestic) of the town in 2017 and 2018 were found 14.13l/day and 16l/day respectively. According to the UWSUAP of the country standard the minimum quantity of water required is taken as 20l/c/day for domestic/household consumption and a non-domestic consumption 30% of the domestic (MoWR, 2011), so the water supply coverage of the town is below the standard. The water supply coverage can be calculated as:

$$\textbf{Water supply coverage} = \frac{\textbf{(annual production}\times\textbf{100\%)}}{\textbf{annual demand}} \ldots\ldots\ldots\ldots\ldots \text{(3.4)}$$

$$\text{Water supply coverage} = \frac{(68916\times 100\%)}{54870}=76.5\%\text{ in 2017 and}$$

$$\text{Water supply coverage} = \frac{(89928.7\times 100\%)}{68346.2}=80\%\text{ in 2018}$$

However, the water supply coverage in the town only satisfies 76.5% and 80% respectively. This value indicates that there is an increase trend in water supply consumption from time to time. The main reason for increasing in the per capita water consumption is that there is growth of supply from 2017 to 2018. But the water demand of the town is not fulfilled due to increase in population, pump failure and seasonal fluctuation of the source. The population of the town is increasing from year to year with increasing demand on existing water supply system of the town. Thus, it is worthwhile to expand the water supply system by improving the source and pumping system to balance supply and demand in the town.

3.2.2. Water Loss Analysis

Unaccounted-for-water additionally articulated as a ratio and, has normally assessed as the difference of net water production delivered to the network and billed consumption use divided by net production and multiplied by 100 (EPA, 2010). The total annual water loss of the water supply system is 20.38% in 2017 and 23.9% in 2018.

$$\text{NRW (\%)} = \left(\frac{\mathbf{WP-BAC}}{\mathbf{WP}}\right) \times \mathbf{100} \ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

$$= \left(\frac{14045.08\text{m3}}{54870}\right) \times 100 = 20.38\% \text{ in 2017 and}$$

$$= \left(\frac{21582.5\text{m3}}{68406\text{m3}}\right) \times 100 = 23.9\% \text{ in 2018}$$

Other indicator of water loss in the water supply system can be determined as per pipe length. This indicator is generally suggested for areas having an uncrowded population settlement pattern. The total length of pipes of size 40mm and above of the entire water supply system is 21.169.6 kilometers. But, as there are some pipes that their diameter not clearly identified, all the pipes greater or equal to 40 mm in diameter have been used to assess the water loss per length of pipes. Using the total pipe length of the entire water supply system, the water loss per kilometer length of pipes were calculated as 1.87 m3/ km/day and 2.793m3/km/day for the year 2017 and 2018 respectively. This figure demonstrates that as length of the pipe expands the measure of water loss every day increments.

3.3. Population Forecasting

Drastic change in an area's economy is the most difficult factor to predict when performing a projection. Using disaggregated projections, population projections can be modified more rationally than projections can flow when developing demand forecasts that reflect these types of events. The population of the city must be determined in different periods after the design period has been fixed. As the population of the area increases in the future, to determine the area's design population, the correct present and past population data must be taken as a census office. The future development of the city mostly depends on the expansion of trade, industrial and surrounding country development, mining discoveries, construction of railway stations, etc. These elements can bring about sharp rises, slow growth, and conditions of stationery, or even decrease populations. Populations increase through births, decrease through deaths, increase or decrease through migration, and increase through annexation. The past and present population were gotten from census office and the Baso Liben Woreda economic development office. It is possible to project or forecast the future population of the city to know the present population from the recent census.

Table 3.3: Population of the town

Year	1994	2005	2010	2014	2015	2016	2017
Population	3717	6502	8249	9528	10077	10641	11219

Table 3.4: Population growth rate for Population Projection, Amhara Region: 2005-2030

YEAR	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
AMHARA	4.67%	4.53%	4.41%	4.25%	4.05%	3.85%

Source: CSA (2013): Report of the Inter Census Population Survey, 2012

Method used by Ethiopian statistics authority: This is the easiest and convenient method to compute with few data at least two census years have been taken and there is no vital register data. This method is useful for projections on short term basis hence extrapolation over a five-year period makes it suitable. It is a hybrid of the geometric and arithmetic methods and corrects the anomalies of the methods. The Ethiopian statistical authority uses the formula to project the population at the end of the required decade / year for most water supply project in the country.

$$\mathbf{P_n = P_0{}^{ern}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.10)$$

Where: P_n=population at n decades or year, P_o=initial population (from census), r=growth rate, n =decade or year, e=constant exponential value (2.718)

Table 3.5: Summary of future population projection for Yejube

Year	Arithmetic	Geometric	Incremental	CSA
2017	11219	11219	11219	11219
2018	11655	11833	11720	11714
2019	12090	12481	12220	12222
2020	12526	13165	12721	12745
2025	14703	17185	15223	15512
2030	16881	22435	17726	18506
2035	19059	29287	20228	21641
2040	21237	38232	22731	24807

Depending on the past, present and future growth rate of the town as well as the nature of the area, the best mathematical method of population forecasting and estimate the future population of the town was selected. Generally speaking, we can simply observe that Yejube City has vast growth opportunities as stipulated in the city municipality's preliminary / feasibility report and documents. In this respect, the method of geometric increase can be selected. On the other hand, the method of percentage error above shows that the CSA (exponential) with less error is more reliable. For Yejube city future population forecasting, therefore, the CSA method is best.

3.4. Future Water Demand Analysis by Using Simple Coefficient Forecast Method

For water utility agencies predicting future water demand is indeed an important task, that included three interconnected operations. The first is supply management, which refers to predicting water demand so that sequenced and timed investment in new supply facilities can be scaled. The second activity is demand management to determine the impact of installation of water meter, detection of leakage, price change, control of leakage, conservation and rationing measures. The third activity is demand-supply management which uses water use forecasts to integrate and coordinate policies on supply and demand management. Water demand modeling are performed not only to resolve the water demand difficulties today, but to avoid in the upcoming years. Simple coefficient methods include per capita, per connection, and unit use coefficient methods. Frequently only water production data for a city as a whole are available, along with an estimate of the city's population so that the per capita method is used. The most frequently used theoretically simple normally used approach is to estimate water use (Q_t) at the future time period(t)by multiplying the future population (P_t) by per capita water consumption rate (q_t) as follow:

$$Q_t = P_t * q_t \ldots\ldots \quad (3.11)$$

Where, (Q_t) Estimate water demand, (q_t) the daily per capita water use (l/cap/day) and (P_t) future projected population, for future time.

$$\textbf{per capita water}(\mathbf{q}) = \mathbf{Q}/((\mathbf{P} \times \mathbf{365})) \ldots\ldots \quad (3.12)$$

The per capita water use rate ca be estimated based on water use records for a particular town, or alternatively, national or regional use rates(standards) can be obtained from the water resource management policy on the country. The major types of water consumptions, modes and levels of services for Yejube Town Water Supply system, are estimated based on MoWR design guide lines for the coming 20 years (2019-2040). The results of analysis made to project water consumption modes and per capita water consumptions considered for the town water supply system are discussed below.

3.4.1. Domestic Water Demand

The demand for water is known as domestic water demand for actual household activity. The water requirement for drinking, washing, and cooking, bathing, cleaning and personal hygiene is included under the category of Domestic water demand. For this town, the modes and levels of services can be categorized as public fountains, Yard connection and House connection.

3.4.1.1. Population Distribution by Mode of Service and Growth Demand

The per-capita domestic water demand for various demand categories varies depending on the size of the town and the level of development, the type of water supply scheme, the socioeconomic and climatic condition climatic of the town. The per capita water demand for an adequate supply level must be determined for various demand category activities based on the basic human water requirements. According to the design criteria prepared in January, 2006 by Ministry of Water Resources, with an increase in awareness within the community on the advantage of using a clean water supply and provision of better services by the water supply unit, the consumption level of the community in each mode of service is expected to increase. In view of this, and as per the recommendation in the MoWR design criteria, the per capita consumption for each mode of services in each year was estimated. Consequently, the present and projected percentage of population served by each mode of service is forecasted by taking the above-mentioned conditions and assuming that the percentage of house and yard tap users will gradually increase during the service period of the project, while the percentage of tap users will decrease substantially because more people will have private connections as living standards and socio-economic

development increase. As a result, the percentage of yard connections and house connections is expected to increase by the end of the design period.
Existing and forecast service levels by town size group are shown in Table 3.8 The table shows the percentage of people using a certain connection type (private house connection, private yard connection, shared yard connection or public tap) in a town of certain size; also, the percentage of people not using the piped water supply (un-served) is shown.

Table 3.8: Population Percentage (%) Distributions by Mode of Service

Connection	Year								
type	2000	2005	2010	2015	2020	2025	2030	2035	2040
HC	1.8%	2.0%	2.3%	2.6%	2.9%	3.3%	3.7%	4.10%	4.50%
YCU	11.6%	13.2%	14.9%	16.9%	19.1%	21.7%	24.6%	27.50%	30.40%
YSU	9.4%	10.6%	12.0%	13.6%	15.4%	17.4%	19.7%	22.00%	24.30%
PT	55.0%	62.3%	64.8%	63.0%	60.6%	56.6%	51.0%	45.40%	39.80%
Un-Served	22.2%	11.9%	6.0%	4.0%	2.0%	1.0%	1.0%	1.0%	1.0%

Source: MoWR water supply design criteria, 2006

The projected population percentage served by each category of demand can be calculated using the formula below:

Population in (category n) = (Population Percentage (%) in Mode of Service) x (total projected population in each year)

In Ethiopia it is obvious that in the small towns there are some peoples that use water from other sources, this is called unserved population. According to the MoWR guideline Unserved population expressed in percentage of the total population.

Table 3.9: Shows the distribution of population by service mode

Description	2019	2020	2025	2030	2035	2040
House connection	347	370	512	685	887	1116
Yard connection	2334	2766	3816	5089	6579	7541
Yard Shared	1882	2218	3056	4071	5259	6028
Public Tap	7407	7213	7911	8402	8613	9873
Un-Served population	244	127	155	185	216	248

In 2040 the House Connection (1116) and Yard Users (7541 YC and 6028 YSU) users expected to increase, whereas Public Tap users shows decreasing from 55.0% to 39.8% with a population of 9873.

Table 3.10: Shows per capita domestic water demand each mode of service

Connection	Year						
type	**2000**	**2005**	**2018**	**2025**	**2030**	**2035**	**2040**
HC(l/day)	98	101.6	104	110	110	110	110
YU(l/day)	25	25.6	26	28	28	28	28
YSU (l/day)	18	18.6	19	21	21	21	21
PT (l/day)	12	12.6	13	14	14	14	14

Source: MoWR water supply design criteria, 2006

The average daily demand for domestic purpose for the town is calculated by multiplying the number of people using a certain type of connection with the per capita demand associated with this type of connection.

Table 3.11: Summery of Growth in Domestic Water Demand

Mode of service	Unit	Year					
		2019	**2020**	**2025**	**2030**	**2035**	**2040**
HTU	(m^3/day)	39.31	42.32	61.74	82.26	106.17	133.04
	l/s	0.45	0.49	0.71	0.95	1.23	1.54
YU	(m^3/day)	66.35	79.16	117.16	155.63	200.39	228.78
	l/s	0.77	0.92	1.36	1.80	2.32	2.65
YSU	(m^3/day)	38.98	46.39	70.37	93.38	120.13	137.15
	l/s	0.45	0.54	0.81	1.08	1.39	1.59
PT	(m^3/day)	104.44	103.24	121.45	128.47	131.17	149.76
	l/s	1.21	1.19	1.41	1.49	1.52	1.73
Total ADD	(m^3/day)	249.08	271.11	370.72	459.74	557.87	648.73
	l/s	2.88	3.14	4.29	5.32	6.46	7.51
	l/c/day	20.4	21.3	23.9	24.8	25.8	26.2

As shown in the Table 3.11 average domestic per capita demand of the town in 2019 and 2040 is estimated to be 20.4l/c/day and 26.2 l/c/day. This figure shows that it can satisfy the recommended water demand (20-25l/c/day) for category-5 towns by the MoWR.

3.4.1.2. Climatic Grouping of the Town

Climate condition is the major factor affecting the population's water demand. In hot days and seasons peoples consumes more water and in the ordinary condition it shows reduction in consumption. To account variation in per capita domestic demand the water demand should be adjusted for climatic condition**.** As per the design criteria (Table 3.12), Yejube with an average annual precipitation of 1367 mm belongs to Group C and therefore an adjustment factor of 0.9 has been taken.

Table 3.12: Adjustment factors for climate

Group	Mean annual PPT (mm)	Factor
A	900 or less	1.1
B	900-1200	1.0
C	1200 or more	0.9

Source: MoWR water supply design criteria, 2006

3.4.1.3. Socio-economic adjustment factors

The socio-economic adjustment factor is decided based on the degree of urban development being studied as the socio-economic conditions play an important role in the quantity of water consumption. Ascertaining the level of cities ' current devolvement and future potential depends on personal judgment in quantifying many developmental aspects due to difficult situations. Yejube is grouped as a town of "Cities under normal Ethiopian conditions" and is therefore classified as a Group C town and has been given a 1.0 adjustment factor (Table 3.13).

Table 3.13: Adjustment factor for socio-economic conditions

Group	Description	Factor
A	Towns enjoying high using standards added with high potential development	1.1
B	Towns having a very high potential for development but lower living standard at present	1.05
C	Town under normal condition	1.0
D	Advanced rural towns	0.9

Source: MoWR water supply design criteria, 2006

The domestic demands were calculated and presented in the table below (Table 3.14) after considering population changes and changes in service mode, per capita demand and applying the adjustment factors.

Table 3.14: Summary of adjusted domestic daily demand

		Year					
Description	**Unit**	2019	2020	2025	2030	2035	2040
	(m^3/day)	226.1	246.25	338.08	420.94	512.84	598.76
Total ADD	l/s	2.62	2.85	3.91	4.87	5.94	6.93
Climatic Factor	-	1	1	1	1	1	1
Socio-economic	-	0.9	0.9	0.9	0.9	0.9	0.9
	(m^3/day)	224.18	244.00	333.65	413.77	502.08	583.86
	l/s	2.59	2.82	3.86	4.79	5.81	6.76
Adjusted ADD	l/c/day	19	20	22	23	23	24

3.4.2. Non domestic water demand of the Town

Non-domestic demand can be disaggregated into institutional demand, commercial(public) demand, and industrial demand. Estimate of non-domestic demand needs a detail study of past, present and proposed public, commercial, institutional and industrial establishments in the town. Moreover, it is also vital to evidently identify the scale of the industry because it directly governs water consumption thus putting impact on the total water consumption pattern of the town. This technique, however, desires well organized evidence recording of the type and scale of water demands of various sectors. However, there's no well-organized information indicating the kind, scale and water consumption pattern of various sectors found within the town. Because of this, the quantity of nondomestic demand is expressed as a proportion of domestic demand the value is fixed after the forecasting of population for identified the category of the town on CSA. The non-domestic water demand for each town is calculated by multiplying the domestic water demand with the non-domestic water demand percentage:

$$NDWD_Y = DD_Y * ND_Y \quad \ldots\ldots\ldots\ldots \quad (3.13)$$

Where: $NDWD_Y$ - Non-domestic demand in given year Y in town
DD_Y - Domestic demand in given year Y in town
ND_Y - Non-domestic demand percentage in given year Y in town

3.4.2.1. Public and Institutional Water Demand

This demand category includes the water requirement of health post, school, market, and public facility government offices. Based on socio economic data of Yejube town, this demand is calculated as 24.7 % of the total domestic water demands as shown that in the table below.

Table 3.1: Public and Institutional Demand

No	Institution	Employ/ bed/ people	per capital consumption	l/d	m^3/d
1	Public office	501	5	2505	2.505
2	Restaurants	50	10	500	0.5
3	Day schools	4804	5	24020	24.02
4	Hotels	120	50	6000	6
5	Bus station	60	5	300	0.3
6	Hospital	40	75	3000	3
7	Health center	45	50	2250	2.25
8	Mosque	30	5	150	0.15
9	Church	60	5	300	0.3
10	Clinic	8	50	400	0.4
11	TVT Collage	1000	5	5000	5
	Total			44425	44.425

Therefore, Percentage of public and institutional demand will be:

44.425(l/day)/179.848(l/day) =24.7% which is nearly 25%.

3.4.2.2. Industrial water demand

Industries in small to medium size Ethiopian towns are in most cases light industry with a demand of some 5 m^3/ha/day. In case of larger industries, the demand will have to be assessed individually for each industry through detailed interviews. Considering the development opportunity of the town in the future 5% of the average domestic demand is taken.

Table 3.16: Summary of non-domestic demand

Description	unit	Year					
		2019	**2020**	**2025**	**2030**	**2035**	**2040**
Adjusted ADD	(m^3/day)	224.18	244.00	333.65	413.77	502.08	583.86
	l/s	2.59	2.82	3.86	4.79	5.81	6.76
public demand (25%)	(m^3/day)	56.04	61.00	83.41	103.44	125.52	145.97
	l/s	0.65	0.71	0.97	1.20	1.45	1.69
industrial (5%)	(m^3/day)	11.21	12.20	16.68	20.69	25.10	29.19
	l/s	0.13	0.14	0.19	0.24	0.29	0.34
Total NDD	(m^3/day)	67.25	73.20	100.10	124.13	150.62	175.16
	l/s	0.78	0.85	1.16	1.44	1.74	2.03

As shown in the Table 3.16 above the non-domestic water consumption of the town at the end of the target year reaches 175.16m^3/day. This event can exert pressure on the total water supply system in the town by increasing the consumption.

3.4.3. Animal Demand

This is the water requirement by the residents to supply their livestock, even though there is no base line survey made at this stage, it is expected that the number of livestock available in the town and animal fattening is highly practice in Yejube town but there are alternative sources for animal demand. So, the animal demand has not included in future water demand forecasting.

3.4.4. Water Requirement for Fire Fighting

Annual volumes required for firefighting purposes are generally small but during periods of need, the demand may be exceedingly large and, in many cases, may govern the design of distribution systems, storage, and pumping equipment. In cost effective design, water required for firefighting shall be met by stopping supply to consumers for the required time and directing it for firefighting purposes. Therefore, considering the size of the town and not to incur additional cost on the project particularly on the reservoir and distribution network, it is proposed not to consider firefighting water requirement separately.

3.4.5. Unaccounted for Water and Loss (UFW)

All The water that can be pumped from the source into the service reservoir and distribution system does not reach to the consumers house. Some portion of the water wasted in different components of the scheme through leakage and overflow from service reservoir, leakage from mains and service pipe connections, defective pipe joint, cracked pipes, loss valve and fittings, under registration of supply meter and premises of consumer to get unmetered supply and Wastage from public tap. All water leakages in the system and unauthorized connections are categorized under unaccounted for water. Loss will be minimal at the beginning of the design period and will increase gradually with time in the expected service life of the new system unless intermediate leakage detection & subsequent remedial work is carried out. It is logical to presume an increase in water loss with time in designing water supply scheme. By keeping the age and state of the water supply system under consideration, UFW can be taken as 20 – 40% of the total water demand (MoWR, 2011). It is up to the designer to come up with a reasonable figure from the recommended range by considering the different factors affecting it.

Table 3.17: Annual water loss

Description	unit	2019	2020	2025	2030	2035	2040
ADD+NDD	m^3/d	291.43	288.12	395.55	492.5	600.02	700.54
	%	22	22.8	23.5	25	28	30
UFW	m^3/d	64.11	65.69	92.95	123.13	168.01	210.16

It is logical that the water loss in the water supply system expected to increase with increasing the age of the material and component of the water supply scheme.

3.4.6. Average per capita Day Demand

The average day water demand is the sum of adjusted domestic water demand, public demand, industrial demand, livestock demand and system water losses. The values calculated in the previous sections are summarized and added to estimate the total average day demand of the project as shown in Table 3.18.

TAD= DD+NDD+UFW…………………..*(3.14)*

Where; TAD-Total Average Demand, DD- Domestic Demand, NDD- Non-Domestic Demand and UFW-Unaccounted for water (Loss and Wastage)

Table 3.18: Summary of Average per capita Day Demand

Description	unit	2019	2020	2025	2030	2035	2040
ADD	m^3/d	224.18	244.00	333.65	413.77	502.08	583.86
	l/s	2.59	2.82	3.86	4.79	5.81	6.76
NDD	m^3/d	67.25	73.20	100.10	124.13	150.62	175.16
	l/s	0.78	0.85	1.16	1.44	1.74	2.03
UFW	m^3/d	64.11	65.69	92.95	123.13	168.01	210.16
	l/s	0.74	0.76	1.08	1.43	1.94	2.43
TDD	m^3/d	355.54	353.81	488.51	615.63	768.03	910.7
	l/s	4.12	4.10	5.65	7.13	8.89	10.54

The total average demand of the town shows increases from time to time, such as in 2019 the total average demand 355.54m^3/day and in 2040 this value increasing to 910.7m^3/day.

3.4.6.1. Variation in demand

There are wide variations in use of water in different months of the year, day of the month and hours of the day. the seasonal variation of demand shows low in winter (cold) seasons and highest in summer(hot) seasons. The water demand of the area is high in summer season due to high water consumption for different purposes. The daily variation is related with the variation of activities and holydays. The water consumption of the people is very high in holydays and festivals. More over daily demand variation may occur due to climatic conditions and economic activities practiced in the area. Also, hourly water demand variations are very crucial as it have extensive array. During the working hours of the day i.e. from 6:00 to 10:00 AM in the morning and from 4:00 to 8:00 PM in evening the demand is high. To regulate the water demand variation the average water demand is multiplied by a certain factor to get the maximum day and peak hour demand.

3.4.6.2. Maximum daily demand

The maximum day demand (MDD) represents the maximum consumption during any one day of the year. The ratio of the maximum daily consumption to the mean annual daily consumption is the maximum day factor. This demand is used to design source capacity, riser mains, and service reservoir.

3.4.6.3. Peak hour demand

The peak hour demand is one of the highest demands within any one hour over the year and estimated taking in to account the possible water collection hours and amount collected by each demand category. Previous studies and experiences clearly demonstrate that peak hour factor is greater for a smaller population. According to water supply design criteria prepared by ministry of water resource and tropics studies the proposed maximum day and peak hour factor are summarized below.

Table 3.19: Maximum Daily and peak hour factor

N0.	Population range	Maximum day factor	Peak hour factor
1	0- 20,000	1.3	2
2	20,001-50,000	1.25	1.9
3	50,0001and above	1.2	1.7

Therefore, Maximum day factor of 1.25 and Peak hour factor of 1.9 are adopted for economical design of this water supply system. The finals of the projected water demand due to adjustment factor as shown below.

Table 3.20: Summery of water demand projection

Description	Unit	Year					
		2019	**2020**	**2025**	**2030**	**2035**	**2040**
Population	№.	12222	12745	15512	18506	21641	24807
TADD	m^3/d	355.54	353.81	488.51	615.63	768.03	910.70
	l/s	4.12	4.10	5.65	7.13	8.89	10.54
APDD	l/c/day	29.1	27.8	31.5	33.3	35.5	36.7
MDF		1.3	1.3	1.3	1.3	1.25	1.25
MDD	m^3/d	462.21	459.95	635.06	800.32	960.04	1138.38
	l/s	5.35	5.33	7.35	9.27	11.11	13.18
	l/c/day	37.82	36.09	40.94	43.25	44.36	45.89
PHF		2	2	2	2	1.9	1.9
PHD	m^3/d	711.09	707.62	977.02	1231.26	1459.26	1730.33
	l/s	8.23	8.2	11.3	14.26	16.89	20.03
	l/c/day	58.18	55.52	62.98	66.53	67.43	69.75

The adequacy of water source to meet the water requirement of the Town population till the end of the design period is an important factor to be considered in rendering sustainable water supply service. As shown in Table 3.20 above the aggregated average per capita consumption of the town in 2019 is 29.1 l/day whereas in 2040 the average per capita consumption raises in to 36.7 l/day.

4. CONCLUSION

The main objective of this paper to evaluate the existing water supply system and water demand scenario analysis and future water demand forecast. The analysis is focused on the evaluation of existing water supply coverage in the town based on the produced and billed water consumption and population of the town, forecasting of water demand for the next 20 years. Water demand forecasting is a vital element in urban planning and sustainable development of a city. In water demand estimation time series forecasting is an imperative area of forecasting in where past perceptions of a similar variable are gathered and examined to build up a model showing the fundamental relationship. The model is then used to extrapolate the time series into what's to come. This study presents water demand scenario analysis in the past as well as future years according to the ministry of water resource urban water supply universal access plan and world bank design criteria. This study identifies the gap between supply and demand in the town in the past two years as well as the water loss. The water production in 2017 and 2018 was below the capacity of the source that it could be produce per year. The water production in 2017 and 2018 was 68916 m^3/year and 89928.7 m^3/year respectively. The annual water production coverage was 32.8% and 42.78% of the capacity of the source i.e. 210240 m^3/year with eight-hour pumping. The aggregated annual average water consumption of the town in 2017 and 2018 was 14.3/c/day and 15.9/c/day respectively. This indicates that the average per capita water coverage of the town is less than 20l/c/day. However, the aggregated average water consumption level was below the minimum requirement when compared with the national and worldwide standard level that have to be needed in each household for different purpose. There is a huge gap between supply and demand with regard to per capita consumption of the dwellers. The water loss in the town shows lower variation and shows medium range with maximum of 20.38% and 24% loss per year in the past two years with increasing from time to time. To illuminate the gap between and supply in the future proper estimation of water demand in the town plays a vital role. The future water demand of the town can be forecasted based on the MoWR water supply design criteria, using simple coefficient forecast methods for the coming 20 years. based on service level and level of consumption, i.e. house connection, yard connection, yard shared connection and public taps. Besides domestic demand, non-domestic demand will be considered such as industrial, commercial, firefighting and other an accounted factor with appropriate adjustment factor due to socio economic and climate factor. The forecasted average water demand of the town in 2019 is 29.1 l/c/day and in 2040 the demand increases to 36.7l/c/day. Up to 2035 the existing source can fulfill the water production by increasing the pumping hour from year to year and after 2035 the town needs additional source to balance supply and demand in the town do to increase in population. Generally, most decision making in urban planning and sustainable development programs are highly dependent on water resource accessibility and future water demand forecasts. Many key decisions concerning water demand management, ecological planning and optimum water resource utilization depend on accurate short- and long-term water demand forecasting. Furthermore, estimating future water demand is vital to the planning of water supply systems as it enables water authorities to know future demand for long-term periods to develop new water sources and expand existing systems capacity. Therefore, it is significant to have a truthful future water demand prediction to ensure adequacy of water in the system to the town by implementing numerous approaches for instance extension in current WDS, construction of new substructure and employment of water resource management strategies.

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