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MODELING WATER DEMAND IN A GROWING PUBLIC UNIVERSITY IN NIGERIA

A. Sobowale[1,*] and K. S. Adeyemo[2]
[1, 2,] DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF AGRICULTURE, ABEOKUTA, OGUN STATE, NIGERIA
Email addresses: [1] *sobowalea@funaab.edu.ng*, [2] *certifiedengineer01@gmail.com*

ABSTRACT
Nigerian university campuses are facing the twin problems of providing portable water of adequate quantity and quality and the sustainability of such supply. This paper examines the water demand status of a public University in Nigeria. Domestic, Public and Industrial water uses were considered while population forecasting was done using regression analysis for a 30 years design period (2018 – 2048). Results reveals possible population increase of 53.8 % by 2048 when the institution will clock 60 years. Water demand is also expected to rise sharply from 5,206 m³ day⁻¹ (2018) to 10,959 m³ day⁻¹ (2048); existing storage capacity cannot satisfy the current needs not to talk of the projected demand hence, a reservoir of about 11,000 m³ will be needed to service the university for the next 30 years; attracting more investments into the water supply system becomes imperative as the existing supplies from groundwater is unsustainable.

Keywords: *Water Demand; Population; University; Sustainability; Growth*

1. INTRODUCTION

Water is important for the sustenance of life and livelihoods. All developmental activities are connected with water, making the universal solvent a very important object of discussion in international context. According to [1], water resources and the range of services they provide, underpin poverty reduction, economic growth and environmental sustainability. Its impact on food and energy security, human and environmental health cannot be over-emphasized; water contributes to improvements in social well-being and inclusive growth, affecting the livelihoods of billions of people all over the world. The scarcity of water in recent years as a result of changing climate makes planning for water supply a daunting task, especially in Sub-Saharan Africa. Nauges and Whittington [2] opined that a better understanding of water use in developing countries is necessary in order to be able to manage and expand water supply systems more effectively; analysis of water demand in these parts of the world is complicated by the fact that, contrary to what is observed in most developed countries, households in developing countries have access to, and may use more than one of several types of, water sources [3]. Another problem is the paucity of pertinent data caused by lack of investment in data gathering mechanisms, leading to gross over estimation or underestimation, as the case may be. Provision of water is majorly the duty of engineers; however, water supply has assumed a multi-disciplinary dimension in recent time, making it necessary to bring all connected disciplines together within the ambit of integrated water resources management (IWRM). Water managers forecast future water demand for a variety of purposes; these analyses can help to understand the spatial and temporal patterns of future water use in order to optimize system operations, plan for future raw water purchases, system expansion, or for revenue and expenditure projections [3]. In Sub-Saharan Africa (SSA), the climate change problem portends great risks for water managers and planners because of its impact of decreasing water availability, increased water demand, intense and more frequent drought leading to higher variability and uncertainties surrounding available water resources. There are basically three responses that water

* Corresponding author, tel: +234 – 806 – 210 – 1020

providers can offer to these challenges; firstly, is to increase water supply, treatment capacity and storage, secondly, is to managing water demand and thirdly, is a combination of both responses. It is therefore imperative to note that understanding the likely future demand trends is essential to preparing adaptation and mitigation plans for climate change. Donkor [4] identified methods and models useful for urban water demand forecasting, applications of these models differ, depending on the forecast variable, its periodicity and the forecast horizon. Whereas artificial neural networks are more likely to be used for short-term forecasting, econometric models, coupled with simulation or scenario-based forecasting, tend to be used for long-term strategic decisions [5]. Much more attention needs to be given to probabilistic forecasting methods if utilities are to make decisions that reflect the level of uncertainty in future demand forecasts; there are also several mathematical methods in use for estimating future demand; these include extrapolating historic trends, correlating demand with socio-economic variables, or more detailed simulation modeling. A university campus has a typical urban status regardless of how remotely sighted it might be, the modern infrastructures found in university campuses and the standard of living as a citadel of learning is an indication of the humongous water demand. Science based universities are among the heavy water users because of the presence of many laboratories, industrial parks, hostels, residential quarters, beautifully maintained lawns and gardens, and even livestock housing as well as irrigated farms. While it is good to have all students and staff of a university accommodated on campus for efficiency of operations and integration; this is not practicable in the Nigerian context because of the huge infrastructural deficit in Nigerian universities. The Federal University of Agriculture, Abeokuta, Nigeria for example is not a fully residential university for both staff and students. The university is a science based university located in the southwestern part of Nigeria; established over thirty (30) years ago, the university has witnessed tremendous growth and an ever-increasing students population enrolled in ten (10) Colleges (faculty) with forty seven (47) academic Departments, one (1) post graduate school, two (2) institutes and eighteen (18) Service centres. The university prides herself as the leading agricultural university on the continent of Africa going by the World University Ranking and a recipient of the prestigious World Bank Centre of Excellence in Agriculture and Sustainable Environment.

Water supply on the campus was planned to be centralized in the first phase of physical development and this system worked effectively within the early period of movement to the permanent site between 1995 and 2000; the university was supplied portable water from the Abeokuta Water Works at Iberekodo, belonging to the Ogun State Water Corporation using an 18 km metered pipe system in conjunction with a 2 million liters concrete distribution reservoir which supply water by gravity around the campus; however, during subsequent years of use, the supply pipeline suffered decline due to irreparable damages caused by pastoralists (*Fulani herdsmen*) in a bid to water their livestock and owing to the fact that asbestos pipes were used which had been reported to be carcinogenic [6]. Since this development, water supply had been erratic and based on standalone water wells drilled into the basement complex rocks underlying the campus with very low yield; over seventy two (72) wells had been drilled on campus, yet, the prevalent water scarcity has continued unabated. The recent plan by the University administration to construct a dam for water supply and irrigation is commendable; this will bring to an end the difficulty of having to use water tankers to augment supply especially in the dry season. This new development requires the evaluation of current and future water demand of the campus as the university has grown beyond its master plan. The recent efforts to transform the university into a full fletched conventional university with the addition of Colleges of Law, Medicine, Social Sciences and Arts will no doubt exacerbate the water crisis which cannot be assuaged by groundwater sources alone. There is therefore the need to plan for the expected increase, so that adequate water infrastructures can be provided on campus. The aim of this study was therefore, to model the water demand of the Federal University of Agriculture, Abeokuta as an important input for the development of a sustainable water supply system on the campus.

2. MATERIALS AND METHODS

2.1 Study site

The study was conducted at the Federal University of Agriculture, Abeokuta, Nigeria (figure 1). The university campus occupies over 100 km^2 land, located about 19 km north east of Abeokuta city center (Lat. 7.2299° N, Long. 3.4387° E); the area has a mean annual temperature and rainfall of 27.1

°C and 1,238 mm respectively; the driest month in the year is December (13 mm) while the wettest month is June (197 mm). The area is underlain by the basement complex hydrogeological formation which is interspaced with aquiferous units with low groundwater yield; the campus is drained by a network of ephemeral streams which flow northwest into the Ogun River. The vegetation around the campus is predominantly derived savannah vegetation with intermittent secondary forest interspaced in the land mass; the soil is predominantly sandy with seven identified soil series, namely Apomu, Egbeda, Ekiti, Iseyin, Iwo, Jago and Oke-Imesi [7].

2.2 Data collection

Pertinent data such as student enrolment, graduation, Staff population, University Master Plan and water distribution infrastructure were obtained from relevant units of the university. Thematic maps of the campus and satellite imageries were obtained from the physical planning unit and some extracted from the internet (Google Earth®).

2.3 Study assumptions

The following assumptions were imposed on the study:

i. The Nigerian University Commission (NUC) staff/student ratio was used for academic staff projection
ii. 30 % of students, academic and non – academic staff population are resident on campus
iii. Service providers such as Taxi/bus drivers, cleaners, gardeners, canteen operators, shop operators etc. were deemed to be 1% of the sum of student and staff population
iv. Industrial water demand was set at 1 % of domestic water consumption due to very low industrial activities
v. All proposed colleges (Law, Medicine and Social Sciences) will be established within the 30 years design period
vi. Appropriate funds for expansion are guaranteed within the design period
vii. 20% of the total water demand was deemed adequate for landscape irrigation during dry season

2.4 Study limitations

The following limitations affected the result from the study:

i. Data used for student population forecasting from 1988 – 2006 comprises of mainly undergraduate students while data from 2007 – 2014 comprises of both undergraduates and postgraduate students
ii. Due to lack of data, students of sub degree programmes (INHURD) and FUNAAB International School and Staff School were not considered in the study.

2.5 Population forecast

Student's population forecast was carried out by first fitting the existing student enrollment data to existing models including exponential, linear, nonlinear, logarithmic, moving average and exponential smoothing using regression analysis; the best model with the highest coefficient of determination, R^2, and the least errors was carefully selected for prediction into subsequent years, while the result was verified by plotting existing data against predicted data to check prediction accuracy. An error term E, which is root mean square error was incorporated into the selected model to enhance accuracy; E is given by equation i below:

$$E = \sqrt{\frac{x^2{}_1 + x^2{}_2 + \ldots . x^2{}_n}{n}} \quad (1)$$

Where; x = error terms, and n = number of error term.

2.6 Water demand estimation

The university campus was treated as an urban center, hence, domestic water use (hostels, lecture halls, offices, and health center), public water use (firefighting, Landscape irrigation, and construction work) and industrial water use (FUNAAB Bakery, Garri/Honey factory, cashew processing Unit, Palm wine factory, seed processing and storage unit, palm oil factory, livestock farms) were considered. Domestic water demand was estimated using 120 $Lday^{-1}$ for residential population while 60 $Lday^{-1}$ was used for non-residential population as shown in Table 1; Industrial Water Demand was estimated using 1% of daily domestic water consumption [8]; demand for firefighting was estimated using Kuiching's formula stated in equation ii below [9] while 20% of the total water demand was considered adequate for factor of safety.

$$Q = 3182\sqrt{p} \quad (2)$$

where Q is quantity of water required in liters/min and P is population

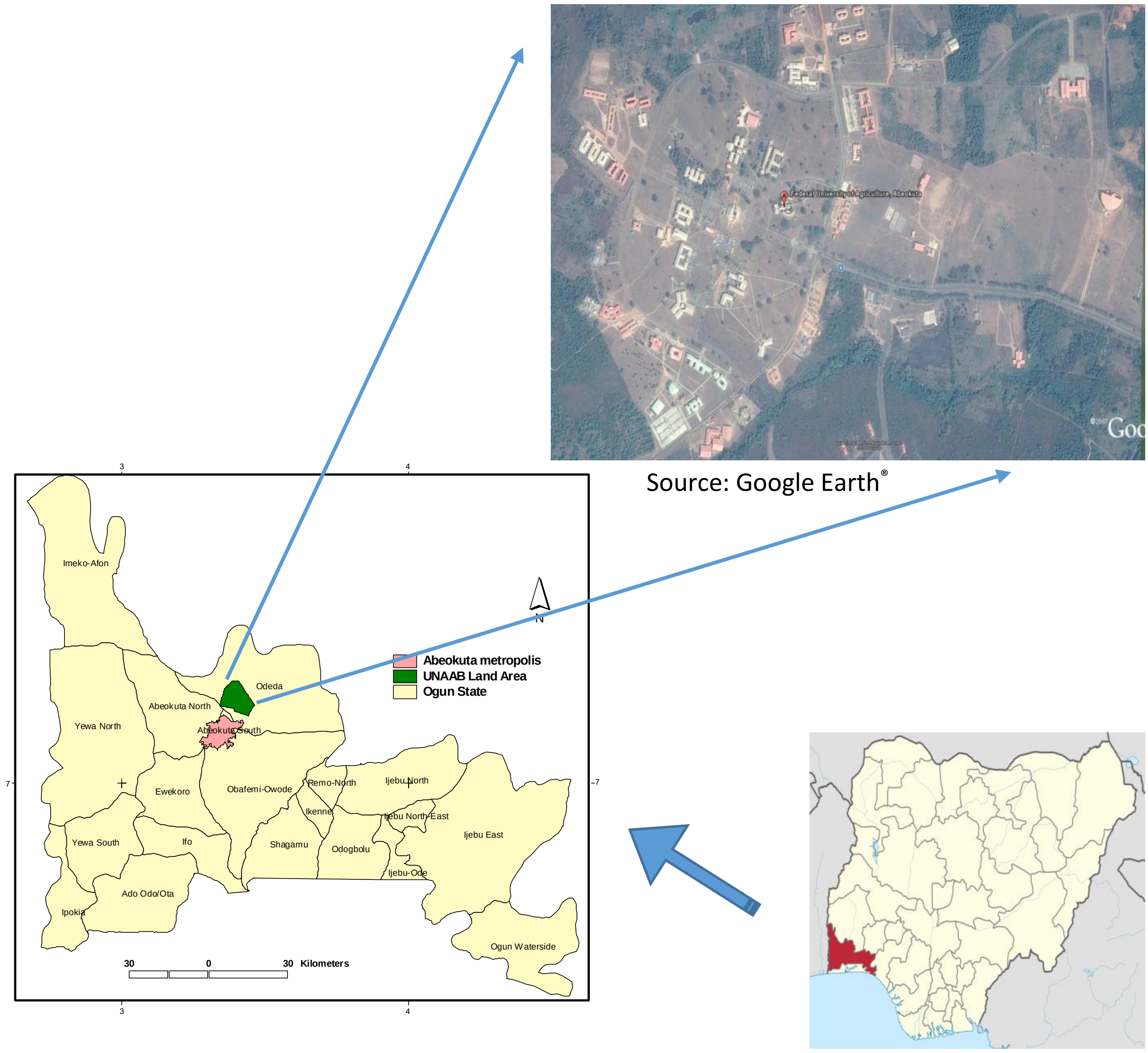

Figure 1: Location and Satellite Image of FUNAAB Campus

Table 1: Nigerian Water Supply System

S/N	Settlement Category	Population	Consumption (Lit cap^{-1} day^{-1})	Water Supply System
1	Urban	>20,000	120	Piped system
2	Semi-Urban or Small Town	5,000 – 20,000	60	Small scale piped system, communal stand pipes
3	Rural	<5,000	30	Hand pumps

Source: National Water Resources Master Plan [8]

3. RESULTS AND DISCUSSIONS

3.1 Population Modeling

Figure 2 shows the 25 years progression of student enrolment in the University; this shows that student population in the university had been steadily increasing over the years as a direct result of physical expansion of facilities, leading to increase in the number of academic programmes. Student enrollment in a Nigerian university does not follow a normal distribution and is usually based on quota allocation by the Joint Admission and Matriculation Board (JAMB); hence projections cannot be made using existing population models according to convention. The best approach will be to fit the existing data to an appropriate regression model with due consideration of the university master plan and/or strategic plan followed by verification of the fit, after which the appropriate model is then used for forecast. It is also pertinent to mention that the results need to be carefully checked to avoid under or over estimation of population by using the university carrying capacity and scenario analysis of establishing new programmes. In Nigerian Universities, growth rate is specifically tied to availability of government funding which is not guaranteed in recent times; hence expansion is somewhat slow in virtually all the public universities. The result shows that the exponential and polynomial models presented a good fit for the data set with R^2 of 97% respectively; however, the 2 period moving average model for time series forecasting presented a better fit as shown in figure 2, with a near 100% R^2. Further verification of this fit by plotting the actual student enrollment data against the model predicted population figures to test for applicability of the model is shown in figure 3.

The 2 – period moving average forecast model is best for the student population forecast with 99.5% level of accuracy, however a root mean square error (RMSE) term was introduced to the forecast data to accommodate unseen factors in the prediction. The model was then used for student enrollment projections till 2048, when the university is expected to clock 60 years of existence as shown in figure 4. The prediction shows that student enrollment will reach 47,411 by 2048. Within the limits of available nonacademic staff population data, the most appropriate model for prediction was the power model as shown in figure 5 indicating that the nonacademic staff population can be forecasted with relative ease. As mentioned earlier, academic staff population was forecasted using the NUC staff student ratio (SNR), this is however rarely the case in most Nigerian Universities; however, it represent the ideal case, hence suitable for use in planning. The NUC benchmark indicated that an SNR of 1:10, 1:15, 1:20, and 1:30 for Veterinary Medicine, Agriculture and Engineering, Sciences and Management disciplines respectively. It should also be noted that 50% of Colleges in FUNAAB has an SNR of 1:15, which included 22 academic Departments or programmes; in order to be conservative in our estimate, a mean SNR of 1:20 was chosen for projection of academic staff population in the university; although, this might lead to overestimation, but it will more likely represent the current status of the University and an acceptable figure for planning purpose. The academic staff projection is presented in Figure 6.

Presently, the university is only resident for some students, while none of the academic staff nor the nonacademic staffs are resident on campus; this is however, not in line with international best practice for university education. It is important for the university to provide accommodation for willing staff, so that adequate cross pollination of ideas may be engendered.

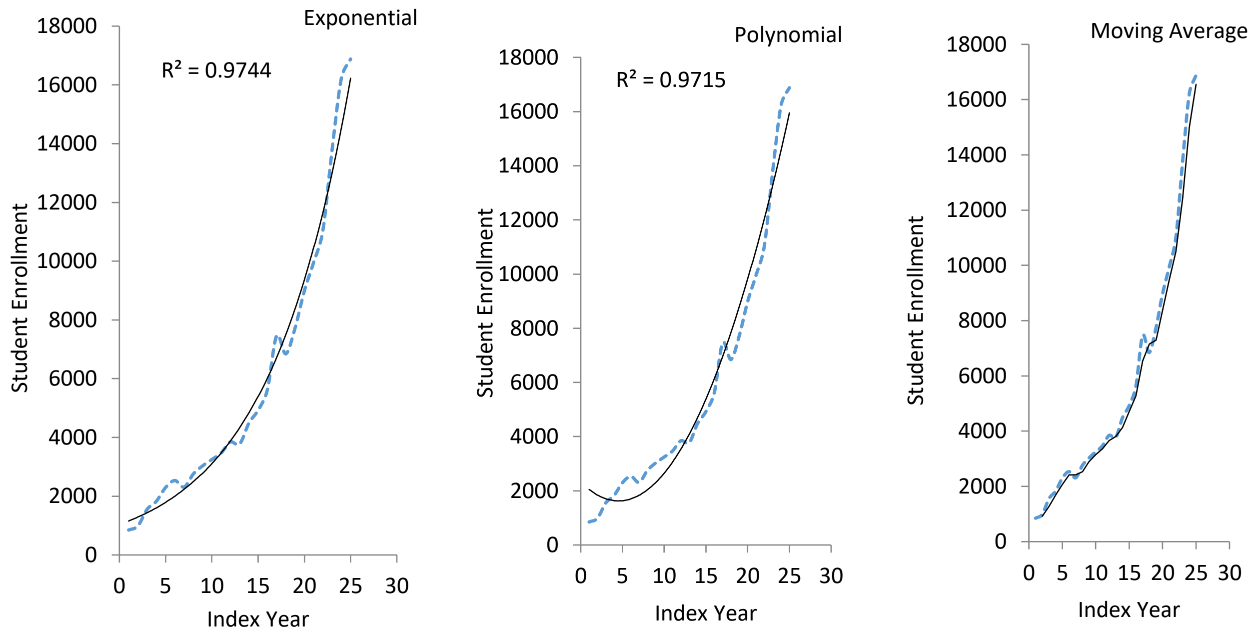

Figure 2: Fitting of student enrollment data (1988 – 2014)

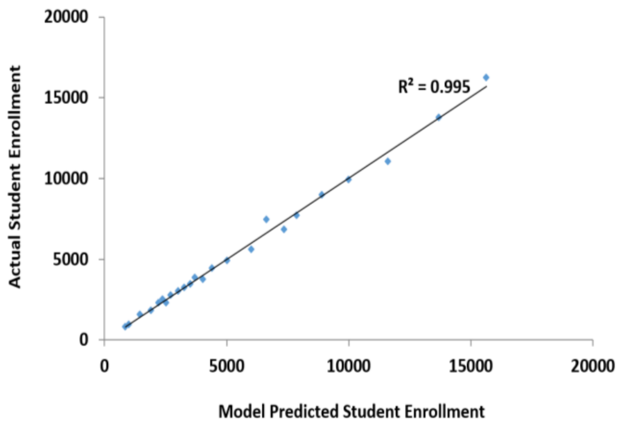

Figure 3: Verification of Student Population Forecast

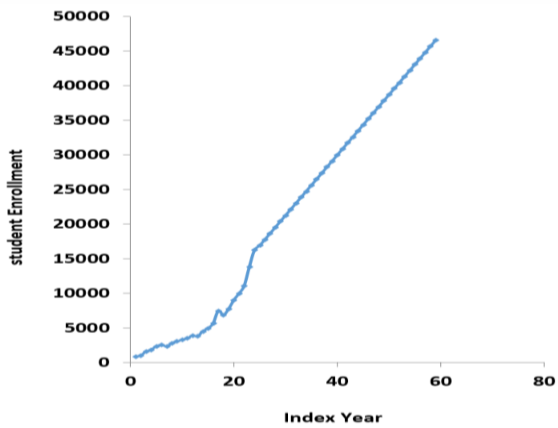

Figure 4: Model predicted Student enrollment (1988 – 2048)

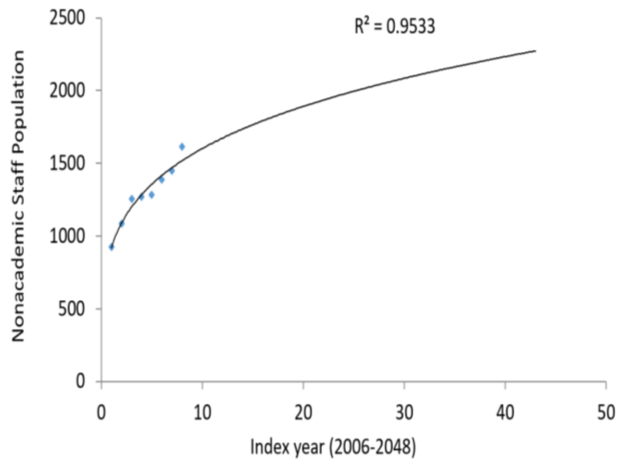

Figure 5: Non-academic staff projection for FUNAAB

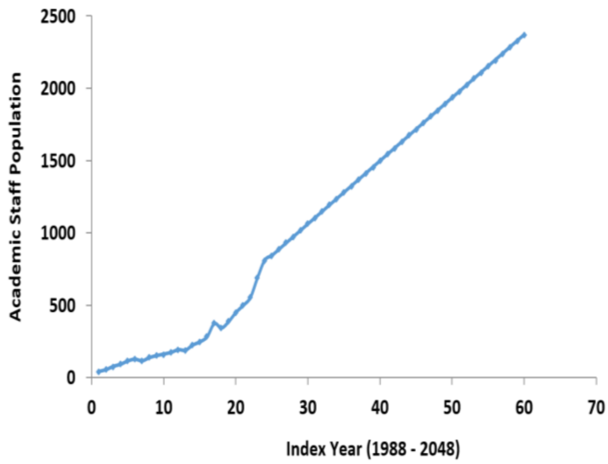

Figure 6: Predicted Academic Staff Population

In fact, it will promote efficiency of operations and the lecturers can become more focused in academic and research matters, apart from the security and other infrastructures it will offer. There is hardly any league of highly rated universities in the world that does not provide accommodation for both staff and students; the academic life must not be bothered with the hustles and bustles of township to encourage scholarly outputs, the present location of the university being about 19 km by road to the Abeokuta city center portends great difficulties for both staff and students. Many of the international prizes winning scholars are usually housed in university accommodations. Figure 7 presents the predicted resident and non-resident population of FUNAAB in the next 30 years, provided the university will implement the plan to provide residential accommodation on campus.

3.2 Water demand estimation

Figure 8 presents the estimated annual water demand of the Federal University of Agriculture, Abeokuta for the next 30 years (2018 – 2048); the trend indicates a steady increase in water demand as a direct result of expected increase in population and activities on campus. The annual water demand on the campus was found to range from 1.9 – 4.0 million cubic meters (MCM) within the forecast period; and this comprises of five distinct water user groups namely, residential population, nonresidential population, industrial water use, firefighting, and landscape irrigation. The result also shows that the nonresident population will use more water than any other user group within the period with an estimated water demand ranging from 0.75 – 1.62 MCM for the next 30 years; the residential water user group which comprise of the 30% of staff and student has a water demand ranging from 0.32 – 0.68 MCM within the design period. It should be noted however, that the university does not have staff accommodation as at now, but the university administration is already working towards providing staff housing as a means of boosting productivity and improving social life on campus. In order to properly understand the expected changes in water demand based on the timeline, figure 9 presents an overview of what should be expected with the different water user groups as we approach the year 2048.

It has become imperative for the university administration to begin to plan for an adequate water supply system on campus, neglecting this important aspect of campus development will lead to serious hampering of academic activities in the university; a sustainable water source needs to be developed while also considering both groundwater and surfacewater sources. There is no doubt that the groundwater sources presently in use on campus cannot sustain the expected population growth. It will also suffice to point out that the existing water supply infrastructure need to be expanded to cope with expected rise in water demand, several new buildings has sprung up on campus which was not hitherto reflected in old University Master plan; extension of the existing pipeline to such buildings will definitely require more investment.

3.3 Expansion of water supply infrastructure

The study revealed a serious need to expand the existing water supply infrastructure on campus if sustainable water supply is to be achieved. Presently, the annual water demand range between 1.9 – 4.0 MCM (2018 – 2048); this implies a daily demand of 5,206 – 10,959 m^3 of water. It is an engineering norm to design a water supply system using the maximum demand within the design life of the system, hence, a distribution reservoir of about 11,000 m^3 capacity should be planned, to serve the campus for the next 30 years. As at present, the campus has one distribution reservoir of 2,000 m^3 capacity, which is already a far cry from the currently needed 5,206 m^3 (2018) capacity; as long as sustaining academic activities on campus is sacrosanct to a university, providing adequate water to support these activities should also be sacrosanct. In view of this, the university administration needs to strategize how to mobilize funds for this important development intervention either through grant sourcing or public – private – partnership (PPP) arrangement.

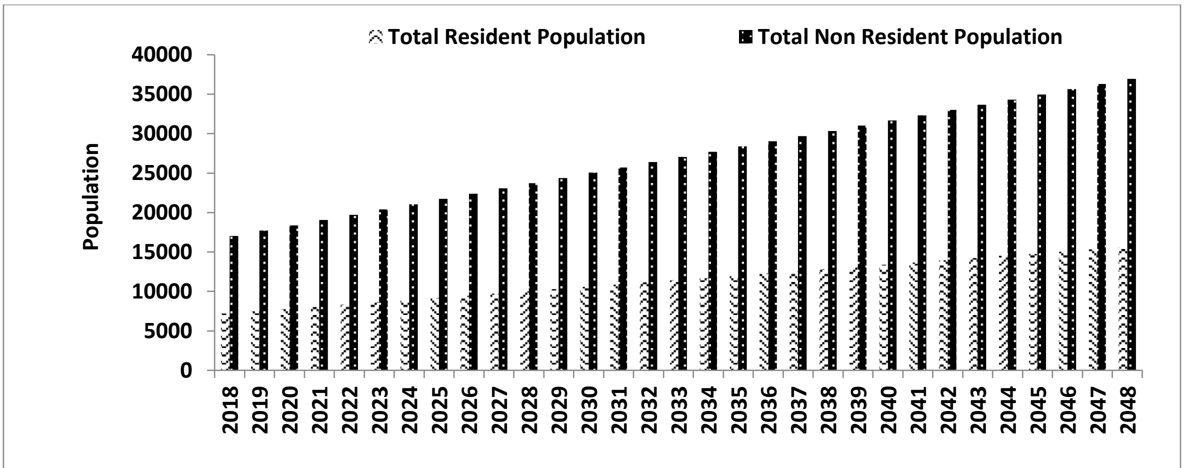

Figure 7: Predicted resident and non-resident population in FUNAAB (2018 – 2048)

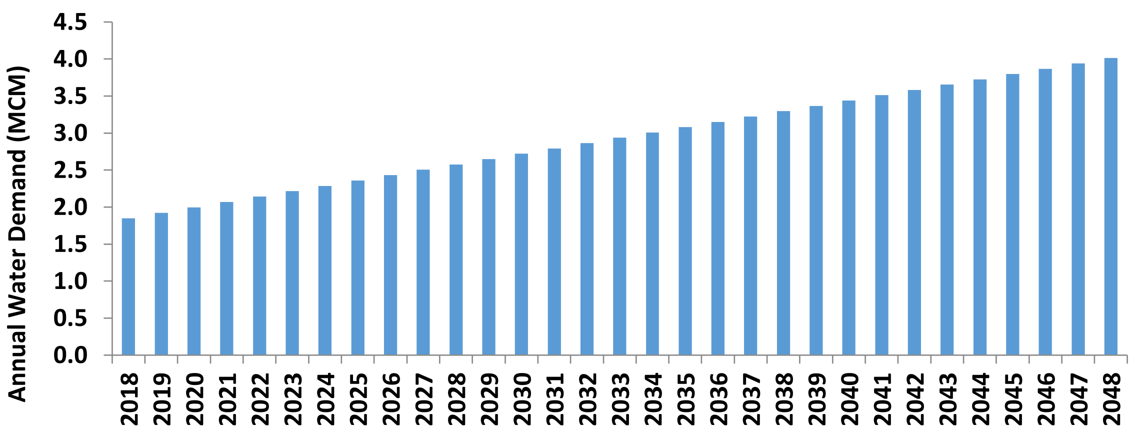

Figure 8: Projected Water Demand of FUNAAB (2018 – 2048)

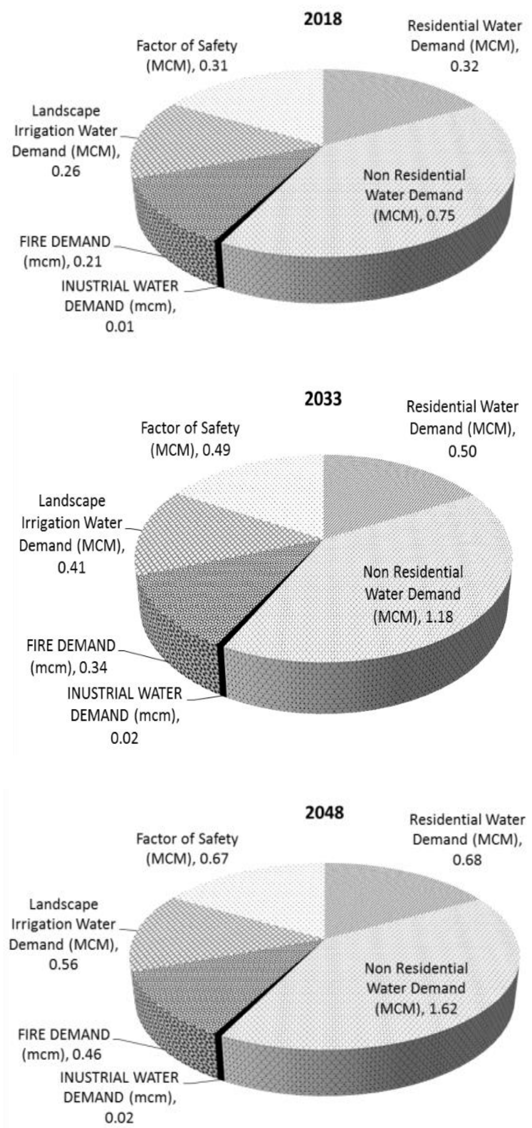

Figure 9: Overview of FUNAAB water demand across important timelines

4. CONCLUSION

Water demand analysis of a fast growing University in Southwest Nigeria had been evaluated, results shows that the present water supply infrastructure cannot support expected population growth and facility expansion. Expected increase in the academic programmes of the university is expected exacerbate the problem; additional investment in the water supply infrastructure is therefore required urgently to ameliorate the impending water crisis. The study also revealed that groundwater sources as presently being used is not sustainable, hence, the need to mobilize funds to upgrade the water supply system. As a short term measure to manage the water demand, the university is advised to implement the installation of water saving devices.

5. ACKNOWLEDGEMENT

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