Measurement and Estimation of Annual Variability of Water Loss at Njuwa Lake Using Class ‘A’ Pan Evaporation Method

A. A. Sadiq1*

1Department of Agricultural Technology, Adamawa State Polytechnic, Yola, P.M.B 2147, Adamawa State, Nigeria.

Author’s contribution

The author has contributed fully to the general organization, literatures data analysis and writing of the manuscript.

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ABSTRACT

Aim: To measure and estimate the annual variability of water loss at Njuwa Lake using Class ‘A’ Pan Evaporation Method.

Place and Duration of Study: Njuwa Lake in Yola South LGA, Adamawa State Nigeria between November, 2019 and May, 2020.

Methodology: Direct measurements of morphometric characteristics of the lake were adopted using simple bathymetric method. Evaporation rates data and other related weather variable for the periods of ten (2007-2016) years were obtained from Upper Benue River Basin Development Authority located near the lake where the volume of water in the lake and the annual water loss were estimated using FAO estimate of water requirement procedures.

Results: The results revealed that Njuwa Lake has morphometric characteristics of 1, 325 m average length, 180m average width, average depth 3.4 m, 238, 500 m$^2$ of surface area, 1,445 m shoreline length and 0.834 m shoreline development with an estimated water volume of 810, 900 m$^3$ respectively. Similarly, highest Class ‘A’ Pan evaporation rates were found in the year 2011, 2007 and 2008 with the corresponding total annual values of 2688.06 mm, 2403.64 mm and 2389.63 mm having an estimated values of water lost from the lake of 641, 102.310 m$^3$ (79.07%).

*Corresponding author: E-mail: sadiqhsadiq6@gmail.com;
INTRODUCTION

Evaporation from water storages and irrigation channels represent one of the major water loss pathways, yet evaporation remains difficult to quantify without large uncertainty. This is especially for small water storages, as the fetch effect on evaporation can be large [1]. The rate and amount of evaporation from water surfaces is also an important consideration in the design of storage reservoirs or for assessing the value of natural lakes for such purposes as municipal and industrial water supply, irrigation, condenser cooling water, hydroelectric power, navigation and recreation [2]. Evaporation represents an effective water loss from the water system and it cannot be neglected because it directly affects the reservoir storage efficiency, the use of productive water, the economy, and peoples' livelihoods [3]. These threats to water supply and food security, mean that management of our water resources through quantification of uses and improvements to water use efficiency are essential [4;5]. Because of its nature, evaporation from water surfaces is rarely measured directly, except over relatively small spatial and temporal scales [6]. Evaporation from water is most commonly computed indirectly by one or more techniques. These include pan coefficients \( \times \) measured pan evaporation, water balance, energy balance, mass transfer, and combination techniques. The most commonly used method in the US for estimating evaporation from small, shallow water bodies, is to measure evaporation from a standard Pan and then multiply by a coefficient.

In Yola South LGA, of Adamawa State Njuwa Lake is considered as the major where irrigation farming, fishing and cattle grazing are intensively carried out by most of the people in the community as explained by [7]. However, in the last decade, farmers in the area had experienced a serious reduction in crop yield, lost of aquatic animals and starvation of grazing animals due to an increase scarcity of water that led to complete drying of the Lake which appeared unprecedented scenario in the past 3-6 decades where the Lake retained water throughout the season. The excessive reduction of water in the Lake is caused by different factors which include poor management, socio-economic, agronomic, institutional and hydro-climatic. Among the hydro-climatic factors water loss due to evaporation process has been reported as the major factor that caused water scarcity in the area [8]. Besides that, the need and value of water is increasing dramatically among the farmers which requires ardent attention of scientific research and technical approaches of estimating the quantity of water lost due to evaporation with the aim of providing workable solutions to the menace in the area. Therefore, this paper saddled with the measurement and estimation of annual variability of water loss at Njuwa Lake Yola using Class ‘A’ Pan Evaporation method.

1.1 Study Area

Lake Njuwa is in Yola South local government, which is located on 9°04’00” and 12°17’00 and 12°33’E with an average altitude of 185m, the population of Yola South local government is 194,607 persons [9]. According to the information from the Rugangye village head and head of the local fishermen, the lake formed naturally from river Benue that was cut off as a result of heavy siltation about 100 years ago, thereby forming a lake [10]. The area experiences two distinctive wet and dry seasons. The rain season starts from May to October,

**Table:**

| Year | Measured Pan Evaporation (mm) | Estimated Water Lost (mm) |
|------|-------------------------------|---------------------------|
| 2013 | 1585.00                      | 378,022.50                |
| 2012 | 1611.54                      | 384,822.50                |
| 2014 | 1663.27                      | 396,822.50                |

**Conclusion:** The rate of water loss was through evaporation was estimated to be greater than the stored water in the Lake in most of the years under study which led to untimely drying of the lake thereby affecting the irrigation farming in the area. Valuable strategies of water use efficiency and irrigation scheduling for effective utilization of the limited stored water in the lake for sustainable food production should be therefore adopted. The research work, however, need further work to make a comparison between the class ‘A’ Pan method and other empirical models method to revalidate the reliability.

**Keywords:** Application; annual variability; class ‘A’ Pan; evaporation; estimation; Njuwa lake; water loss.
while the dry season commences from November to April and mean daily temperature fluctuates with season normally from 25°C to 45°C, and mean annual rainfall received from the range of 150-1000m. Cold and dusty weather is from December to January and then followed by intense heat of March to April [11].

2. MATERIALS AND METHODS

To estimate evaporation losses from the Njuwa Lake data on evaporation rates and other hydro-climatic data that affects water losses such as atmospheric temperatures, relative humidity, wind speed, solar radiation, and rainfall amount were obtained from Agro-meteorological station of the Upper Benue River Basin Development Authority (UBRBDA) Yola for the period of ten years (2007-2016) [12] which is located about 1.5 km from the lake. Njuwa Lake morphometric characteristics were determined using simple bathymetric method which includes; surface area, maximum length, mean length, maximum width, mean width, maximum depth, mean depth, shoreline length and shoreline development. The volume of water in the lake and the amount of water losses by evaporation was determined using FAO estimates of water requirements method [13]. While other related weather variables were compared with annual rates of evaporation using charts and figures to express the relationship that exist among them respectively.

The morphometric characteristics were calculated as follows;

Maximum length (Lmax): is the distance, in a straight line, between the two farthest points on a lake.

Minimum length: is the average length of a lake.

Maximum depth (Dmax): the distance, in a straight line, between the two deepest points on a lake. Simple bathymetric method was adopted by sketching simple outline of a lake basin and then measuring and recording water depths at a number of locations within the lake by the use of weighted line, marked in meters.

Mean depth (z): is the average water depths of a lake obtained by dividing the total number of readings taken and average them.

Maximum width (zmax): is the maximum distance between the two widest points of a lake, measured without crossing land, and at a 90º angle to the lake’s axis.

Mean width: is the average width of a lake obtained by dividing the total number of readings taken and average them.

Surface area (A): was obtained by multiplying the length and width of the lake

\[ A = L \times W. \]  

(1)

Plate 1. Portrayed gradual drying of Njuwa Lake in yola south LGA which might be attributed to excessive evaporation rates

(Source; Pictures taking by the author)
Fig. 1. The study area

Fig. 2. Satellite map of the Njuwa Lake (Captured by the author on 12th May, 2020)
Water volume \((V)\): is the total amount of water in a lake basin, and it is usually expressed cubic meters \((\text{m}^3)\). It was calculated by multiplying the mean depth and the surface area.

\[
\text{Volume } (V) = \text{mean depth (z)} \times \text{surface area (A)}
\]

\(2\)

Shoreline length: is the linear measurement of a water body’s entire perimeter, at a given water level. It was obtained using Global Positioning System (GPS), Android software by walking close to the lake perimeter.

Shoreline development (SLD): refers to the length of a lake’s shoreline relative to a circle of the same area. The mathematical equation provided below was used to calculate the shoreline development of a lake.

Shoreline development \((\text{SLD}) = \frac{L}{\pi^\frac{1}{2} A} \) equation \(3\)

Where \(L\) = Shoreline length \(A\) = surface area of the lake

3. RESULTS

STEP 1. Annual data of Class ‘A’ Pan evaporation rates for the periods of ten (2007-20016) were depicted on Table 2.

STEP 2. The total annual corrected evaporation (in mm) were divided by 1,000 to convert the evaporation in meters which were portrayed on Table 3.

STEP 3. The converted evaporation rates in meters (m) were then multiplied by the water surface area of the lake (in m\(^2\)=238, 500 m\(^2\)) to find the total water losses by evaporation in cubic meters (in m\(^3\)) for each year under study as shown on Table 4.

STEP 4. Estimated total amount of water remaining in the lake by subtracting the total water losses by evaporation in cubic meters (in m\(^3\)) from the calculated volume of water in the Lake (in m\(^3\)= 810, 900 m\(^3\)). The results were portrayed on Table 5.

4. DISCUSSION

4.1 The Morphometric Characteristics of Njuwa Lake

Njuwa Lake morphometric characteristics were presented on Table 1. The result shows that the lake has an average length of 1325 m. The length of the lake can influence the depth at which waves can mix water and/or bottom sediments in a lake [14]. Thus, Njuwa Lake is not an exceptional. In addition, the lake average width was found to be 180 m having a measured average depth of 3.4 m. Mean depth of a lake has much to do with the potential for water volume estimation. The surface area of 238, 500 m\(^2\) was determined. Thus, water level and surface area can change dramatically with drought and/or flood conditions. However, drought conditions used to increase the shoreline development on the lake while flood conditions also lead to deposition of sediments materials and debris in a lake subsequently reducing the depth, width and length of the lake. Thus, [15] reported that Njuwa Lake is an ox-bow lake where fishing festival and intensive irrigation farming are carried out in past years until recently when it dried up mainly as a result of siltation effects affecting agricultural activities in recent years. Surface area is one of the most important morphometric parameters of a lake because it not only describes the size of a lake, but also plays a major role in a lake system it help predict the potential volume of water in the lake which may favors the rate of evaporation. Furthermore, the estimated volume of water in the lake was 810, 900 m\(^3\) which is equivalent to 810, 900, 000 liters of water. Similarly, the shoreline length was measured as 1, 445 m. Lake’s shoreline is important morphometric characteristics because it defines the area where a water body interfaces with the land which may change considerably depending on rainfall and lake levels. This type of morphometric characteristics is important for planning various activities such as sinking of boreholes, digging of wells, predicting of water table levels, bed preparations and construction of farmsteads along the perimeter of the lake. Similarly, at high water levels, and depending on the slope of the land, a lake may have small amounts of aquatic vegetation along its shoreline. However, if water levels were to fall, the reduction in water depth along the lake’s shoreline could result in a dramatic increase in aquatic plant growth. This is because when the water becomes shallow, sunlight may be able to reach larger areas of the lake bottom, providing the necessary energy [14]. The shoreline development of 0.834 m was also determined for the lake. Lake’s shoreline development it is an important morphometric characteristics because it helps to assess the amount of potential wildlife habitat available for a lake. Lake with greater amount of shoreline development, there is more of an interface between the water and surrounding land which is often translates into more habitat for fish, birds,
and other wildlife to raise their young. It is also described the gradual changes in the lake perimeter over time. Therefore, Njuwa Lake has a potential annual decrease of 0.834 m along its perimeter and the surrounding environment which may have negative consequences on water availability for agricultural activities in the area.

4.2 Measured and Estimated Annual Variability of Water Losses due to Evaporation on Njuwa Lake

Tables 2, 3 and 4 presented the results on annual variability of evaporation rates on Njuwa Lake. It was revealed that the measured evaporation rates varies annually, where the year 2011 was revealed to have highest Pan evaporation rate with the corresponding values of 2688.06 mm having an estimated evaporation rate on Njuwa Lake of 641, 102.310 m³ representing about 79.07% volume of water lost. This assertion might be attributed to the relatively high annual maximum temperature 414°C (average of 34.5°C) and the highest total annual Sunlight of 2855.10 hrs/min as in ref [12] respectively. Thus, the finding is in conformity with the report of [16] explained that incoming solar radiation is the principle source of energy for evaporation. Likewise Ref [17] explained that temperature is usually extremely high resulting to high evaporation rate. In addition, 2007 and 2008 were measured as the second and third highest Class ‘A’ Pan evaporation rates of 2403.64 mm and 2389.63 mm with an estimated values of 573,268.140 m³ and 569, 926.755 m³ of water loss on Njuwa Lake representing about 70.7% and 70.29% respectively. Conversely, in the years 2013, 2012 and 2014 were measured with lowest Pan evaporation rates with the corresponding values of 1585.00 mm, 1611.54 mm and 1663.27 mm; m respectively. The estimated water loss by evaporation on Njuwa Lake for these years were found with the equivalent values of 378, 022,500 m³, 384,352.290 m³ and 396, 689.895 m³ representing about 46.6%, 47.4% and 48.9% volume of water lost. The remaining four (4) years under study(2009, 2016, 2010 and 2015) were found to have moderate evaporation rate measured from the class A Pan with the values of 1675.91 mm, 1690.20 mm, 1691.99 mm and 1773.98 mm respectively. The estimated total water losses by evaporation on Njuwa Lake for the corresponding years were found with the values of 399,704,535 m³, 403, 712,700 m³, 403, 535.615 m³ and 423,094,230 m³ representing total volume of 49.3%, 49.72%, 49.77% and 52.16% correspondingly. Furthermore, Table 5 described the estimated remaining total amount of water in the Njuwa Lake in cubic meters (in m³), where 2011, 2007 and 2008 were estimated with low total amount of water in the lake (below average) with the corresponding values of 169, 797,690 m³ (20.95%), 237,631.860 m³ (29.3%) and 240, 973.245 m³ (29.71%) respectively. This is due to fact that the measured water lost was highest in these years compared to the other years under study. This might be connected to high atmospheric temperature, high wind speed values and low total annual relative humidity respectively. Thus, 2011, 2007 and 2008 was considered as drought spells periods at Njuwa Lake which led to reduction in crop yield under irrigation farming due to drying of the lake by excessive evaporation. Conversely, 2013, 2012 and 2014 were estimated with relatively above average of total amount of water retained by the lake 432, 877.500 m³ (53.4%), 426, 547.710 m³ (52.6%) and 414, 210.105 m³ (51.1%) correspondingly. This is a consequence of low evaporation rate induced by some weather variables such as the high total annual value of relative humidity and relatively low atmospheric temperature [12]. Despite the fact the year 2012 possessed the maximum total annual temperature of 422°C (an average of 35.16°C). According to Ref [18] reported a rapid increase in surface water temperature, implies increased evaporation rates. But the presence of relative humidity may reduce the temperature heat effects on both the atmosphere and water surface thereby reducing the rate of water loss in the lake. An increase in humidity in the surrounding environment of the evaporation pan may affects the rate of evaporation [19-20]. In these years, drying of Njuwa Lake may be very slow and the agricultural activities (fishing, farming and grazing) were preferentially achieved due the relative quantity of water stored by the Lake. While the remaining years (2009, 2016, 210 and 2015) were described with an average volume of water stored in the lake having an average corresponding values of 411, 195,465 m³ (50.7%), 407, 787.300 m³ (50.28%), 407, 360.385 m³ (50.23%) and 387, 805.770 m³ (47.84%).

4.3 An Overview of Some Edaphic Causes of Water Loss at Njuwa Lake Irrigation Farming Area

Sadiq AA, Abdullahi M.[8] had reported recently some soil factors that led to high trends of water
Table 1. Measured morphometric characteristics of Njuwa lake

| Average Length (m) | Average Width (m) | Average Depth (m) | Surface Area (m^2) | Volume of Water (m^3) | Shoreline Length (m) | Shoreline Development (m) |
|--------------------|------------------|-------------------|-------------------|----------------------|----------------------|--------------------------|
| 1325               | 180              | 3.4               | 238,500           | 810,900              | 1445                 | 0.834                    |

Table 2. Class ‘A’ pan evaporation rates (in mm) for the periods of ten (2007-2016)

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| 2007 | 209.44 | 242.08 | 299.48 | 279.56 | 187.02 | 180.24 | 255.80 | 100.75 | 120.23 | 125.29 | 192.77 | 210.98 | 2403.64 |
| 2008 | 210.67 | 247.45 | 339.41 | 280.21 | 211.27 | 158.12 | 151.07 | 108.12 | 113.69 | 158.64 | 205.92 | 205.06 | 2389.63 |
| 2009 | 156.55 | 167.90 | 220.32 | 181.92 | 146.43 | 122.07 | 106.54 | 92.37 | 100.28 | 108.84 | 125.36 | 147.33 | 1675.91 |
| 2010 | 160.22 | 170.00 | 224.56 | 227.03 | 159.52 | 107.44 | 86.14 | 79.42 | 97.01 | 107.80 | 126.40 | 146.45 | 1691.99 |
| 2011 | 151.70 | 166.32 | 226.29 | 211.98 | 162.54 | 229.53 | 142.96 | 90.28 | 80.94 | 112.34 | 611.57 | 501.61 | 2688.06 |
| 2012 | 187.16 | 167.40 | 213.22 | 208.5 | 131.83 | 121.18 | 89.34 | 69.90 | 103.48 | 101.49 | 105.57 | 112.47 | 1611.54 |
| 2013 | 133.72 | 156.75 | 171.23 | 191.79 | 166.69 | 127.90 | 92.88 | 87.19 | 99.24 | 107.78 | 112.05 | 137.78 | 1585.00 |
| 2014 | 148.78 | 156.48 | 195.13 | 187.52 | 117.55 | 153.31 | 101.34 | 83.43 | 95.45 | 166.33 | 126.79 | 131.16 | 1663.27 |
| 2015 | 150.20 | 172.76 | 208.54 | 225.27 | 210.87 | 149.30 | 114.34 | 90.18 | 83.50 | 108.67 | 130.35 | 130.00 | 1773.98 |
| 2016 | 153.19 | 170.84 | 200.66 | 209.75 | 161.65 | 112.15 | 99.69 | 96.29 | 105.5 | 107.75 | 128.80 | 143.93 | 1690.20 |

Source: [12]

Table 3. Converted annual evaporation rates from millimeters (mm) to meters (m)

| S/n | Years | The total annual corrected evaporation (in mm)/ 1,000 | Converted annual evaporation rates to meters (m) |
|-----|-------|-----------------------------------------------|-----------------------------------------------|
| 1   | 2007  | 2403.64                                       | 2.40364                                      |
| 2   | 2008  | 2389.63                                       | 2.38963                                      |
| 3   | 2009  | 1675.91                                       | 1.67591                                      |
| 4   | 2010  | 1691.99                                       | 1.69199                                      |
| 5   | 2011  | 2688.06                                       | 2.68806                                      |
| 6   | 2012  | 1611.54                                       | 1.61154                                      |
| 7   | 2013  | 1585.00                                       | 1.58500                                      |
| 8   | 2014  | 1663.27                                       | 1.66327                                      |
| 9   | 2015  | 1773.98                                       | 1.77398                                      |
| 10  | 2016  | 1690.20                                       | 1.69200                                      |
Table 4. Estimated total water losses by evaporation in cubic meters (in m$^3$)

| S/n | Years | The total annual corrected evaporation (in mm)/ 1,000 | Converted annual evaporation rates in meters ($\times$238,500 m$^2$) | Total water losses by evaporation in cubic meters (in m$^3$) |
|-----|-------|------------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------|
| 1   | 2007  | 2403.64                                              | 2.40364                                                       | 573,268.140                                             |
| 2   | 2008  | 2389.63                                              | 2.38963                                                       | 569,926.755                                             |
| 3   | 2009  | 1675.91                                              | 1.67591                                                       | 399,704.535                                             |
| 4   | 2010  | 1691.99                                              | 1.69199                                                       | 403,539.615                                             |
| 5   | 2011  | 2688.06                                              | 2.68806                                                       | 641,102.310                                             |
| 6   | 2012  | 1611.54                                              | 1.61154                                                       | 384,352.290                                             |
| 7   | 2013  | 1585.00                                              | 1.58500                                                       | 378,022.500                                             |
| 8   | 2014  | 1633.27                                              | 1.66327                                                       | 396,689.895                                             |
| 9   | 2015  | 1773.98                                              | 1.77398                                                       | 423,094.230                                             |
| 10  | 2016  | 1690.20                                              | 1.69200                                                       | 403,112.700                                             |

Table 5. The estimated remaining total amount of water in the Njuwa Lake in cubic meters (in m$^3$)

| S/n | Years | Total water losses by evaporation in cubic meters (in m$^3$) | The estimated remaining total amount of water in the Njuwa Lake in cubic meters (in m$^3$) | Stored volume of water in (%) | Lost volume of water in (%) |
|-----|-------|-------------------------------------------------------------|----------------------------------------------------------------------------------|--------------------------------|----------------------------|
| 1   | 2007  | 573,268.140                                                 | 237,631.860                                                                     | 29.30                         | 70.7                       |
| 2   | 2008  | 569,926.755                                                 | 240,973.245                                                                     | 29.71                         | 70.29                      |
| 3   | 2009  | 399,704.535                                                 | 411,195.465                                                                     | 49.30                         | 50.7                       |
| 4   | 2010  | 403,539.615                                                 | 407,360.385                                                                     | 49.77                         | 50.23                      |
| 5   | 2011  | 641,102.310                                                 | 169,797.690                                                                     | 49.07                         | 50.93                      |
| 6   | 2012  | 384,352.290                                                 | 426,547.710                                                                     | 47.40                         | 52.60                      |
| 7   | 2013  | 378,022.500                                                 | 432,877.500                                                                     | 46.60                         | 53.40                      |
| 8   | 2014  | 396,689.895                                                 | 414,210.105                                                                     | 48.90                         | 51.10                      |
| 9   | 2015  | 423,094.230                                                 | 387,805.770                                                                     | 52.16                         | 47.84                      |
| 10  | 2016  | 403,112.700                                                 | 407,787.300                                                                     | 49.72                         | 50.28                      |

Table 6. Some edaphic causes of water loss at Njuwa lake irrigation farming area

| S/n | Factors                           | Frequency (n=250) | Percentage (p=100%) |
|-----|-----------------------------------|------------------|---------------------|
| 1   | Soil type                         | 40               | 16                  |
| 2   | Slope extent                      | 55               | 22                  |
| 3   | High rate of soil infiltration    | 45               | 18                  |
| 4   | Siltation and sediment deposition | 65               | 26                  |
| 5   | Siltation of tributary            | 45               | 18                  |

Source: [8]

In the study area, where siltation and sediment deposition over Njuwa Lake over years appeared as the main factor limiting water availability by majority of the farmers (26%) affecting the yield negatively as presented on Table 6. Hence, Ref [21] further explained that deforestation causes rapid increases in erosion and sediment loads in rivers, in turn causing faster sedimentation of reservoir storage and net water storage declines. Similarly, slope extent has contributed in the water scarcity scenarios in the area accounted about 22% of the respondents. About 18% of the farmers revealed that siltation of tributary to Njuwa Lake had also led to water shortage that caused poor crop growth and low profitable farming (Table 6). Some farmers along river Chochi which directly takes water to Njuwa lakes in the area used the river as water source for irrigation. Even though, the river is seasonal in nature which dries up before the onset of rainy season due to sedimentation effects [8]. Therefore, the farmers mostly cultivate vegetables than cereals to avert from drying up effects of the river. Generally, the bulk of the irrigation water is sourced from rivers and dams and conveyed via open channels or...
pipelines to irrigated farms for storage before use or direct application to root zones [22]. Upstream effects may include siltation, salination, and deforestation; [23;24,25,26]. High rate of soil infiltration have conceived by 18 % of the farmers in the area to had caused water deficit below the irrigation requirement in the area (Table 6). Clayey and loamy soils were the predominant soils in the area characterized by low infiltration rate due to the presence of micro-pore spaces. Thus, the soils possessed high water holding capacity which might not have significant effect of water deficit in the area [8]. Only 16 % of the respondents in the study area agreed that soil type in the farm locations was among the edaphic factors that caused insufficient of water for agricultural activities in the area (Table 6). However, the clayey-loam soil characteristics are described by low infiltration and high hydraulic conductivity thereby having low impact on reduction of water in the irrigation site respectively.

5. CONCLUSIONS

Evaporation losses from lake storage can potentially be large, particularly in irrigation areas of Yola South LGA of Adamawa State where water losses through evaporation process remains one of the major factor causing scarcity of water at Njuwa Lake which led to untimely drying of the lake and considered as the principal threat to both agricultural and non agricultural activities in the area. Class ‘A’ Pan method of estimating evaporation was adopted in this study due to its simplicity, widely used and considered as accepted method globally despite its limitations. It was estimated that in the year 2011, 2007 and 2008 water lost through evaporation was highest than the stored or retained water in the lake with the corresponding percent values of 79.07%, 70.70% and 70.29% from the storage volume respectively. Conversely, low water losses through evaporation was estimated in the year 2014, 2012 and 2013 with about 48.9 %, 47.4% and 46.60 % out of the storage volume of water in the lake which might be attributed to climatic changes and physiographic dynamic nature of the lake environment.

6. RECOMMENDATIONS

To reduce the excessive water losses due to evaporation process in the lake and to maintain and manage the limited water resources for effective and sustainable agricultural production, it is therefore recommends that;

1. Farmers should be trained intensively on the appropriate and effective water use efficiency techniques and strategies (irrigation scheduling and frequency, water management etc) towards utilizing limited available water in the Lake to avoid untimely drying.
2. There is need to conduct another research using equation models method (such as water balance, energy balance, mass transfer, combination techniques etc) for the comparative analysis and validation with the findings obtained from this research using Class ‘A’ Pan method, and also the relationship between the weather variables and the evaporation losses should be studied as further research.
3. Farmers should also adopt the use of low water use potential crops and drought resistant varieties for timely harvest and optimum yield.
4. Government at all levels should provide modern techniques of reducing evaporation rates on the Lake and also farmers should employ the use of both cultural and agronomic soil and water conversation techniques such as mulching methods, tillage practices, appropriate bed constructions, preventing seepage from beds among other.
5. Similarly, there is need to rejuvenate the Njuwa Lake through increasing the depth, width and length that were silted by sediment deposition so that it can store adequate quantity of water.
6. In addition, federal government should consider the completion of Chochi irrigation project which will equally curtail the menace of water availability and improve will profitable farming and boost the food production for the growing population in the study area and the country at large.

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COMPETING INTERESTS

Author has declared that no competing interests exist.
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