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**Original Research Article**

# Assessment of Water Resources Availability and Demand in Malete Watershed, North-Central Nigeria

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**ABSTRACT**

*Water is one of the basic human needs and it is imperative for sustaining quality of life. If water is not properly managed, it can lead to its scarcity. In recent times, there has been high demand for water in Malete community due to the establishment of Kwara State University which attracts small scale industries and housing estates. This study assesses the water availability and water demand in Malete watershed using Soil and Water Assessment Tool (SWAT) model coupled with Mapwindow GIS. The hydrological process of the watershed was performed using 30 years weather data obtained from Nigeria Meteorological Agency (NIMET) and spatial data which include Soil map, Land use map and Digital Elevation Model (DEM) to determine the quantity of available water resource in the watershed. Water demand was also determined with average water demand per capita and projected population. Geometric growth rate method was employed to estimate the projected population based on domestic and public factors and the population data was obtained from National Bureau of statistics. From the result, the future water demand was estimated at $3.05 \times 10^4$ $m^3$/day while the available water resources was $1.89 \times 10^5$ $m^3$/day. Thus, the result indicated that the water in the watershed is sufficient to cater for the projected water demand.*



## 1. INTRODUCTION

Water is one of the most essential resources on earth. It is sometimes scarce and is fundamental for living (Zakari et al., 2011). The accelerating growth of human population, the rapid advances made in industry and agriculture have resulted in a rapidly increasing use of water by man, to the extent that the availability of water as well as the control of excessive water has become a critical factor in the development of every region of the world (Williams, 2010). The earth's hydrosphere has about 1.36 billion $km^3$ water and 75% of the earth's surface is covered with water containing 97% salty and 3% fresh. Only 1% of the water is available for human consumption and is unevenly distributed (Gleick, 2006). Uneven distribution of water may be attributed to precipitation, geographical landscapes, accessibility, population distribution, and socio-economic factors (Koby, 2002).

Water availability in a river basin is the minimum flow velocity during rain and dry seasons, measured in the river basins output/outlet and it is affected by several factors, such as climate, soil topography and geology, and variety of vegetation lies above ground (Irsyad, 2008). Water measured in the outlet point is called surface runoff, and it consists of surface water and ground water that will be considered potential water source to be used as water supply for various human needs (Ojha et al., 2008). Furthermore, water availability is defined by Post et al. (2012) as the total volume of river flow from water catchment area. Accordingly, water balance equation is often used for basic analysis of water availability in a region. For example, to estimate the amount of water available for drinking or irrigation, Q or runoff is used (Ojha et al., 2008). Therefore, to ensure availability of adequate water for human use, water resource managers need to be able to estimate the amount of water that enter, pass through, and leave an individual watershed. This is a challenge because the relative magnitudes of the transfers of individual components in the hydrologic cycle can vary greatly (Gupta, 2011). In the hydrologic cycle, water availability can be estimated from the amount of water that can be utilized (Dingman, 2015).

Drinking water supply and demand can be varied from place to place with availability and accessibility sources of water supply which include rivers, lakes, springs and small streams. At present, the earth's inhabitants withdraw 30% of the runoff that is accessible but about 20% of the total runoff is remote and not readily available to meet water consumption (Bergman, 1995). Some regions have excess amount of water, most possibly in rainy areas while water is deficit in dry regions. The severe scarcity and demand for water leads to competition for the resources and aggravate regional or national political tensions and socioeconomic problems (UNHDR, 2019). Water demand is the outcome of unplanned urbanization, industrialization, and rapid population growth. Demand for water can also exist if ground water is exploited without replenishment. Also, where there is high population concentration and rapid growth, water demand trends to increase dramatically. The most important demographic trend affecting water resources is population growth. Population growth and urbanization, together with changes in production and consumption have placed unprecedented demands on water resources (Postel et al., 1996). However, reports by international bodies like the United Nations (UN) and World Health Organization (WHO) and other non-governmental organizations have indicated that water supply in not always commensurate with demand worldwide. According to WHO (2010), only 32% of rural population in developing countries have access to safe drinking water. Today, a large percentage of the rural population in developing countries continues to live without adequate access to safe and convenient water supply and sanitation (Dada, 2009).

In Nigeria, more than 90% of rural areas and 60% of urban areas face water related problems (ADF, 2007). In recent times, the establishment of Kwara State University in Malete has resulted in a greater upsurge of the population of the area which has affected the economic and social activities of the area. This trend will continue in the next few decades and therefore, it is essential to explore how the future water resources of the area will look like in order to have better plan for a sustainable social-economic development. This study adapted the use of soil and water assessment tool (SWAT) coupled with Mapwindow GIS interface to assess the water availability and demand in the study area in order to determine if the water availability in the watershed will satisfy the future water demand.

## 2. MATERIALS AND METHODS

### 2.1. Description of the Study Area

The study area is located in Moro Local Government area of Kwara State. It is a rural settlement which lies between latitude 8°42'31.83''N and longitude 4°28'09.25''E. The topography is a fair representative of surrounding plains which can be described as undulating with very broad and gentle slopes. Malete has a low water level which makes distribution of water require more and efficient equipment and storage facilities. The main occupation of Malete inhabitant are farming and hunting. The available sources of water which are used in water distribution systems in Malete are flowing river, bore hole and well water. Figure 1 shows the map of the study area.

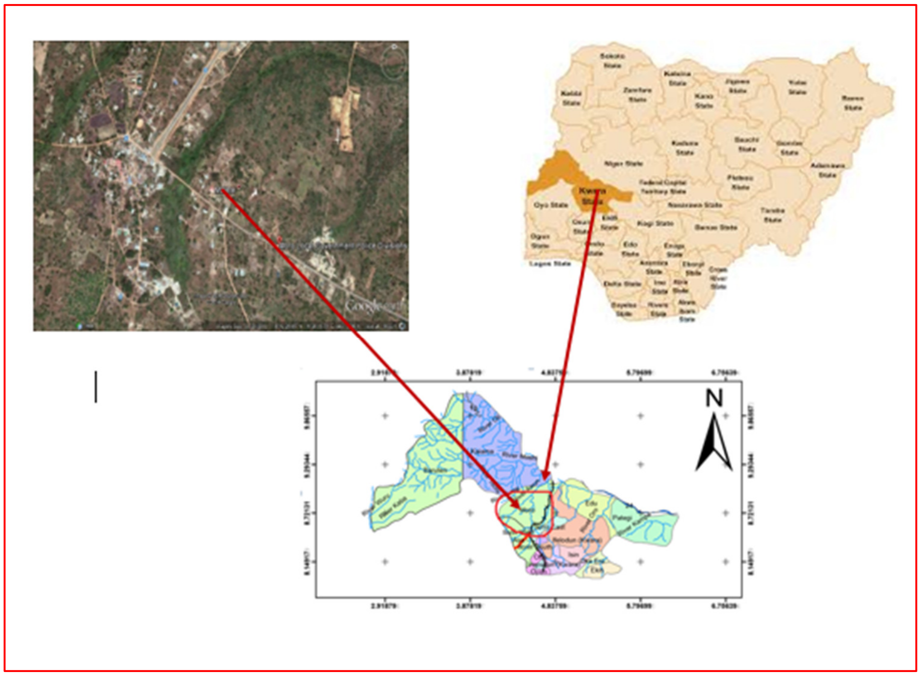

Figure 1: Map of Kwara State showing the study area

## 2.2. Model Input Data

SWAT modeling data requirement are spatial data and temporal data. The spatial data include Digital Elevation Model (DEM), Soil and Land use maps, whereas the temporal data which is also known as weather data include daily precipitation, minimum and maximum temperature, relative humidity, wind and solar radiation. Table 1 shows the model input data and Figures 2 and 3 show the Digital Elevation Model (DEM) and Land use of the study area.

Table 1: Model input data collection and processing

| S/N | Data Type | Description | Resolution | Source |
|---|---|---|---|---|
| 1 | Topography | Digital elevation model | 90 m × 90 m | Shuttle radar topographical mission |
| 2 | Land use map | Land use classification | 1 km | Global land cover |
| 3 | Soil map | Soil types and textures | 10 km | Digital soil map of the |
| 4 | Weather | Daily precipitation, Min and Max temp, Relative daily humidity, Wind, Solar radiation | Daily | Nigeria metrological agency (NIMET) |

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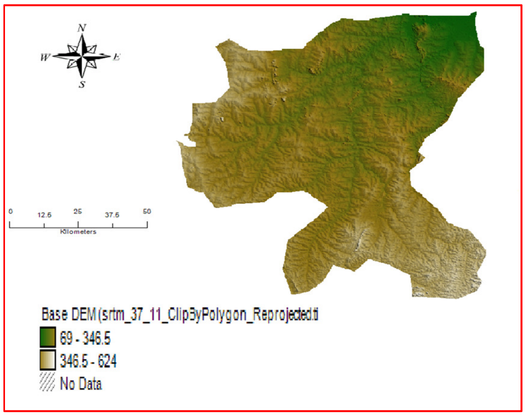


Figure 2: Digital Elevation Model (DEM)

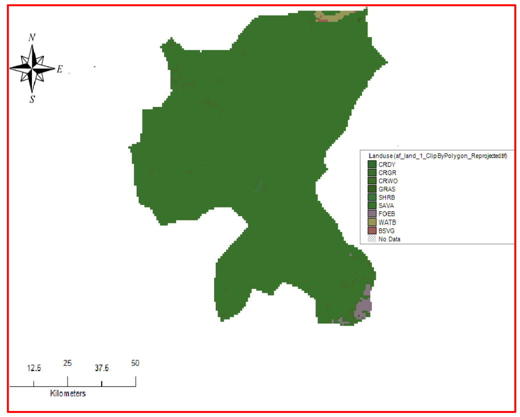


Figure 3: Land use map of the study area

**2.3. Model Setup and Configuration**

This study adapted SWAT model to delineate watershed with soil and land use data, and weather data definitions. One of the steps in model set-up consists of the identification of the hydrological response units (HRUs) for the water balance components. For this purpose, the river network for the Malete watershed was extracted from DEM, using standard analytical techniques contained in the MWSWAT GIS interface with a minimum upstream contributing area of 50 $km^2$ used as a threshold value for defining river cells. In total 7 sub-basins were defined and 79 HRUs (unique land use/soil combinations within sub-basins) were generated. Within the SWAT conceptual framework, the representation of the hydrology of a basin is divided into two major parts: (a) the land phase of the hydrological cycle and (b) the routing of runoff through the river network. For modeling the land phase, the river basin was divided into sub-basins, each one of which is composed of one or several hydrological response units (HRUs), which are areas of relatively homogeneous land use/land cover and soil types. The characteristics of the HRUs define the hydrological response of a sub-basin. For a given time step, the contributions to the discharge at each sub-basin outlet point is controlled by the HRU water balance calculations (land phase). The river network then connects the different sub-basin outlets, and the routing phase determines movement of water through this network towards internal control points and finally towards the basin outlet

For modeling purposes, a watershed is partitioned into a number of sub watersheds or sub basins. The use of sub basins in a simulation is particularly beneficial when different areas of the watershed are dominated by land uses or soils dissimilar enough in properties to impact hydrology. Referencing different areas of the watershed to one another was achieved by partitioning the watershed into sub basins. Figure 4 shows the delineation of the watershed into sub-basins.

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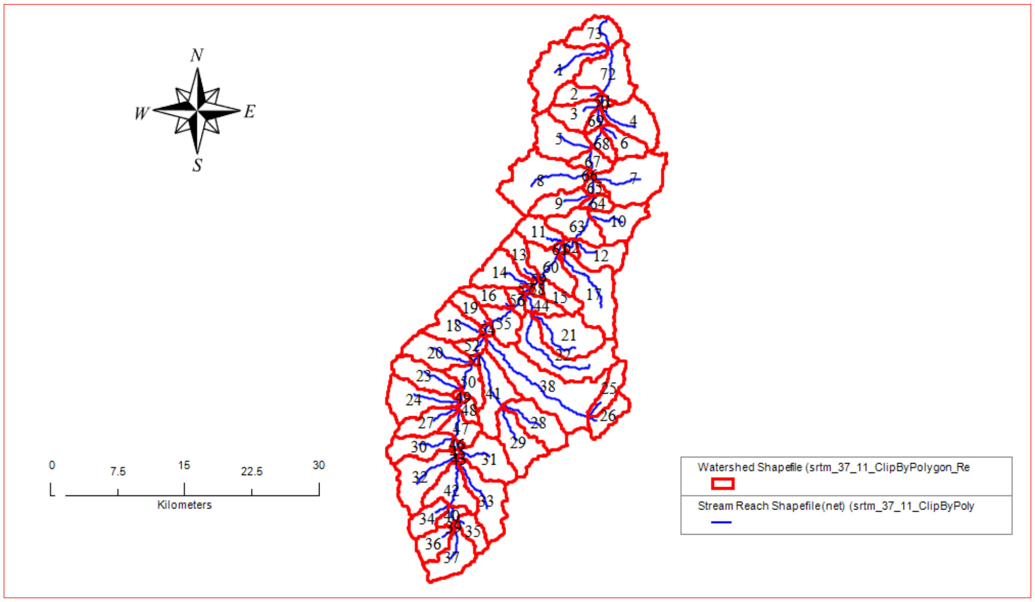


Figure 4: watershed delineation into sub basins

### 2.4. Estimation of Water Availability

The water availability for this study was obtained by modelling the study area watershed, separating flow of water to different basins with the use of SWAT model. Water availability was obtained by multiplying the Area ($km^2$) of each sub-basin around the coordinates of the study area with their respective water yield (m). Water yield is the average amount of fresh water that runs off in an unregulated watershed. In this study the sub-basins selected around the coordinate of the study area are seven (7) which are sub-basin 20, 48, 64, 65, 66, 67 and 68. The water availability was calculated using Equation (1).

$$Z = \frac{\sum A_i \times \sum Y_i}{X \times T} \quad (1)$$

Where; $Z$is Water availability ($m^3$/day); A is Area of sub-basins; Y is Water yield of sub-basins; X is Number of projected years, 30 (years) and T is Number of days in a year, 365 (days)

### 2.5. Estimation of Water Demand (Domestic and Public)

The population data for the study area was 102,780 obtained from National Bureau of Statistics (NBS, 2006) and the growth rate of 1.4% was used to forecast the population for the year 2018 and 30 years projected population, which is 2048 using geometric growth rate method. The projected population is expressed in Equation (2).

$$P_t = P_0(1 + r)^n \quad (2)$$

Where $P_t$ is Projected Population; $P_o$, the Present Population; r, Growth rate and n is number of years (Nigami et al., 2016).

Domestic water use is the water used in residential houses for the purpose of cooking, washing, toilet flushing, drinking and laundry while public water is the water used in schools, hospitals, market among others. In Nigeria, the recommended water demand per capital per day by the World Health Organization

(W.H.O.) for domestic and public are 100 l/p/day and 65 l/p/day respectively. The water demand and total water demand are expressed in Equations (3) and (4) respectively.

$$\text{Water demand} = \text{Average water demand per capita per day} \times \text{Projected population} \quad (3)$$

$$\text{Total water demand} = \text{Domestic water demand} + \text{Public water demand} \quad (4)$$

## 3. RESULTS AND DISCUSSION

### 3.1. Water Balance Components Prediction

In hydrology, water balance is used to describe the flow of water in and out of a system, manage water supply and predict where there may be water shortages, and used in irrigation, runoff assessment, flood control and pollution control. Figure 5 shows the percentage of water balance components. The result revealed that surface water has the highest accumulated water having 37% of the total water availability while lateral flow accumulated for 0% of the total available water in the sub-basin of the study area.

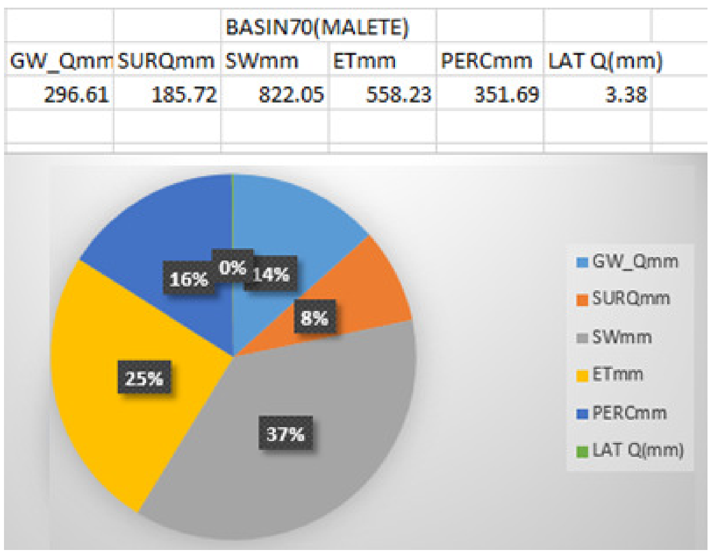


Figure 5: Percentage of water balance components

### 3.2. Estimation of the Available Water Resources

Tables 2 and 3 show the water yield and area of selected sub-basins of the study area. It was revealed that sub-basins 66 and 68 have the lowest and highest water yield of 485.03 mm and 551.91 mm respectively while sub-basins 66 and 64 have the lowest and highest water yield of 0.80 km$^2$ and 224.17 km$^2$ respectively.

From Equation (1), the available water resource in Malete watershed was estimated at $1.89\times10^5$ m$^3$/day for the projected year 2048. And from Equation (2), the projected population for 2018 and 2048 were estimated at 121,582 and 184,505 people respectively. Also, using equation (3), the domestic and public water demand for projected population of 2048 were computed at $1.86\times10^4$ m$^3$/day and $1.20\times10^4$ m$^3$/day respectively. Therefore, Equation (4) was used to compute the total water demand which was estimated at $3.05\times10^4$ m$^3$/day.

Table 2: Water yield of the sub-basins

| Sub-basin | Water Yield (mm) |
|---|---|
| 20 | 485.61 |
| 48 | 536.34 |
| 64 | 485.39 |
| 65 | 527.57 |
| 66 | 485.03 |
| 67 | 526.97 |
| 68 | 551.91 |
| Total | 3598.82 mm = 3.60 m |

Table 3: Area of the selected sub-basins

| Sub-basin | Area ($km^2$) |
|---|---|
| 20 | 89.18 |
| 48 | 47.91 |
| 64 | 224.17 |
| 65 | 168.95 |
| 66 | 0.80 |
| 67 | 41.44 |
| 68 | 1.39 |
| Total | 573.84 $km^2$ = 573,840,000 $m^2$ |

## 4. CONCLUSION

SWAT model coupled with Mapwindow GIS was adapted to evaluate the impact of water availability on future water demand for Malete catchment. The projected water demand was estimated at 3.05 X $10^4$ $m^3$/day while the total water availability of the selected sub-basins of the study area was 1.89 X $10^5$ $m^3$/day. Thus, the result revealed that the water available in the Malete watershed is higher than the projected water demand. Therefore, there is sustainability of water resources for future water demand.

## 5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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