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# EVALUATION OF IRRIGATION APPLICATION EFFICIENCY: CASE STUDY OF CHANCHAGA IRRIGATION SCHEME

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**Abstract**
Water is an integral issue needed to attain the desired targets but good quality water for irrigation purpose is gradually become scarce. The seasonal nature of rainfall can give rise to water stress at critical periods of growth. This research attempts to evaluate the irrigation application efficiency of Chanchaga irrigation scheme, Minna, Niger state. A hand auger was used to bore to a desired depth to remove samples of the moist soil. Samples of the moist soil removed was placed in a can, covered and taken to the laboratory. The specific gravity (apparent) of the soil particle and the depth of water applied were determined using volumetric method, water application efficiency is determined using Gravimetric Method of Soil Moisture Content ($P_w$) Determination. The moisture content of the field after irrigation water is applied falls between the ranges of 51.1% and 51.5%, with an average of 51.28%, in this case the average amount of water applied is about 4.68%, this shows a little increase in the moisture content of the soil in the field. It was concluded that the efficiency of water application obtained is adequate and a good result considering the available management practice in terms of system operation, monitoring and evaluation.

**Keyword**: Application, efficiency, Irrigation, water, scheme

## 1. Introduction

Growth in the world population has taken its toll on several activities of which agricultural activities are not left out. The activities of deforestation and inefficient use of water for productivity have reduced the availability of water resources (da Silva *et al*., 2013). Thus, the need for evaluating irrigation systems which aims at determining its efficiency, uniformity, and adequacy which should be in line with other performance indicators (Latif and Ahmad, 2008). They further stated that the performance of the system is usually determined under actual field operating conditions. The desire to boost agricultural production has called for the genuine need to really appraise an irrigation system in its entirety with regards to management (Alicia, 2009).

The performance of a farm irrigation system is determined by the efficiency with which water is diverted, conveyed and applied taking into account the uniformity of application in each field on the field. Lorenzini and Wrachien (2005) defined a system performance "as the degree to which the system's products and services respond to the need of their stakeholders. The performance assessment should be a regular, short duration process for investigating suspected critical short falls in performance. The performance indicators are measurable variables that describe the condition of a system and its changes over time and space (Mayer, 2008; Dumanski and Pieri, 2000).

Water distribution uniformity and irrigation efficiency have in the recent times become important tools for the modern day agricultural activities of which Nigeria is not left out. Thus, irrigation systems and schemes which have higher values of these indicators are considered to be best when compared with those of lower values. Application efficiency of water on any crop is defined as the ratio between the amount of water retained in the root zone of the plant and the amount of applied irrigation water hence the need for an improved use of water for production is important as it has the highest demand for water (da Silva *et al*., 2013).

Water is an integral issue needed to attain the desired targets but good quality water for irrigation purpose is gradually become scarce. The seasonal nature of rainfall can give rise to water stress at critical periods of growth; thus, irrigation would however, remove the limitations imposed by lack of rainfall giving room for all year round arable farming and removing the risk of un-seasonal droughts in the face of escalating global population (Thomas, 2006). As available water resources become scarcer, more emphasis is given to efficient use of irrigation water for maximum economic return and water resources sustainability. Rainfall patterns have become increasingly erratic. Optimum crop water management is thus inevitable if we are to increase and sustain agricultural production for the ever increasing population (Webster, 2014). This call for supplemental irrigation to provide the deficit in soil moisture needed for optimum crop growth. This requires appropriate methods of measuring and evaluating how effectively water is extracted from a water source and used for maximum crop yield. Inadequate irrigation application results in crop water stress and yield reduction. Excess irrigation application can result in pollution of water sources due to the loss of plant nutrients through leaching, runoff and soil erosion. Howell (2008) stated that not much work has been done as regards water application efficiency which is due to its difficulty in establishing the necessary parameter for the study (Koumanov *et al.*, 2006). They also identified flow of water below the root zone of a crop as the major problem.

Irrigation water is also required for field preparation, crop establishment, crop growth and development, within-season system maintenance, delivery of chemicals, frost protection, and other uses such as dust control. This study attempts to evaluate the irrigation application efficiency of Chanchaga irrigation scheme, Minna, Niger state with the objective of determining the depth of water applied on a research field and deriving the moisture content and specific gravity of the selected field soil sample required for calculating the efficiency of water application.

## 2. Materials and Methods

### 2.1 Description of the Study Area

The Chanchaga Irrigation Scheme, In Minna, Niger State. Niger State is situated in North central part of the Federal Republic of Nigeria. It lies in the savanna zone of the tropics between latitude $8^{o}10^{1}$N and $11^{o}30^{1}$Nand longitude $30^{o}30^{1}$E. Its climate is influenced mainly by the rain-bearing South West winds from the oceans and the dry dusty or harmattan North East winds (air masses) from the Sahara Desert. There are mainly the rainy and the dry seasons. The rainy season begins in April and ends in October and the dry season starts in October /November and ends March. The mean monthly rainfall record from 1998 to 2006 ranges from 0.57mm to 215.1mm with February/March is having the minimum and September having the maximum occurrence.

**2.2 Sample Collection**

A hand auger was used to bore to varying depth; 0-20cm, 20-50cm and 50-100cm to remove samples of the moist soil. Samples of the moist soil removed was placed in a can, covered and taken to the laboratory. The samples were weighed and oven dried. The moisture content was determined using the mathematical formula stated below:

Therefore, Moisture content $P_w = \frac{X_3(g)}{X_{2(g)}} \times 100\%$ (1)

where: $X_1$ is weight of moist soil (g), $X_2$ is weight of water-free soil after drying (g), $(X_1 - X_2) = X_3$ is loss of weight in drying (g).

The amount of moisture was converted to volume percentages $P_v$ as follows:

$P_v = P_w A_s$ (2)

where: $A_s$ is apparent specific gravity of the soil (which varies based on the soil textural classification). The computed moisture was converted to depth of water in order for the values to be used in accordance with Equation 2. Moisture content of the soil on depth basis was obtained by multiplying the volume percentage ($P_v$) by the depth of soil (D) removed by the auger.

Thus,

$d = \frac{P_w}{100\%} \times A_s \cdot D$ (3)

where: d is depth of water before and after irrigation corresponding to $W_1$ and $W_2$ as explained initially, $P_w$, $A_s$ and D assumed meanings defined in the preceding sections.

**2.3 Determination of Water Application**

Gravimetric method of measurement was used to determine the moisture content of the various samples collected from the various locations to determine the application efficiency of the irrigation scheme.

The soil moisture content was expressed by weight as the ratio of the mass of water present to the dry weight of the soil sample. Another method of ratio of volume of water to the total volume of the soil sample was also used. The soil samples were dried to a constant weight before and after measurement. The weight of water is the difference between the weights of the wet and oven dry samples at $105^0$ until a constant weight of the sample is achieved.

**2.4 Determination of Water Application Efficiency Using Field Data**

For water application, various samples of soil were collected and taken to the laboratory for the determination of soil moisture content using an oven drying, heating to a temperature of $105^oC$; samples were kept in the oven for about 72 hours. Moisture content percentage values are converted to depth units to enhance their use in the efficiency of water application equation (Egharevba, 2009). Water application efficiency for the study area was determined and evaluated using field data by

$$E_a = \frac{(W_2 - W_1 + nE_t)}{W_a} \times 100\% \quad (4)$$

where: $E_a$ = application efficiency of water (%), $W_2$ = Depth of water in the soil after irrigation (cm), $W_1$ = Depth of water in the soil before irrigation (cm), n = Number of days between sampling dates (days or hours), $E_t$ = Consumptive use or Evapotranspiration expressed (mm/day) and $W_a$ = depth of water applied (cm)

## 2.5 Determination of Depth of Water ($W_a$) Applied on the Field (Basin)

### *2.5.1 Volume Method*

Known volume of water (15 liters) was siphoned through a pipe of 50mm diameter and the time taken for water to be dispensed was recorded.

Average Time in seconds was 6.4 s

Discharge rate (Q) = $\frac{\text{Volume } (m^3)}{\text{Time (s)}} = \frac{0.015m^3}{6.4\ s}$ = $0.0023m^3/s$

Total time taken to fill or flood one basin by the siphon was two minutes, forty-three seconds (i.e 2.43 minutes).

Area of Basin = $(1.2m \times 5m)$ = $6.0m^2$

$$(\text{Discharge rate } \times \text{Time}) = (\text{Area } \times \text{Dept (D)of water applied}) \quad (5)$$

QxT = $(0.0023m^3s^{-1}\ x\ 163.2s) = 0\ .375m^3$

Therefore, $D = \left(\frac{0.375m^3}{6.0m^2}\right) = 62.56m$

## 3. Results and Discussion

### 3.1 Results

The results of the various soil samples analyzed for moisture content before and after the experiment are presented in Tables 1 and 2 respectively. Table 3 shows the values of the efficiencies at different moisture contents.

Table 1: Values of the soil samples; Moist and dried with their corresponding Moisture content (%) (Before Irrigation)

| S/No | Moist Weight ($W_1$)g | Dried Weight ($W_2$)g | Moisture Removed ($W_1$ - $W_2$)g | Moisture Content (%) |
|---|---|---|---|---|
| 1. | 230.89 | 157.39 | 73.5 | 46.7 |
| 2. | 186.83 | 127.53 | 59.3 | 46.5 |
| 3. | 277.34 | 189.44 | 87.9 | 46.4 |
| 4. | 262.86 | 179.06 | 83.8 | 46.8 |
| 5. | 205.74 | 140.34 | 65.4 | 46.6 |

Table 2: Values of the soil samples; Moist and dried with their corresponding Moisture content (%) (After Irrigation)

| S/No | Moist Weight ($W_1$)g | Dried Weight ($W_2$)g | Moisture Removed ($W_1$ - $W_2$)g | Moisture Content (%) |
|---|---|---|---|---|
| 1. | 283.28 | 187.48 | 95.8 | 51.1 |
| 2. | 251.81 | 166.21 | 85.6 | 51.5 |
| 3. | 272.28 | 180.08 | 92.2 | 51.2 |
| 4. | 254.20 | 167.90 | 86.3 | 51.4 |
| 5. | 230.05 | 152.15 | 77.9 | 51.2 |

Table 3: Values of Moisture Content (%) with Corresponding Values in Depth Units and Calculated Efficiency of Water Application ($E_A$)

| S/N | Before irrigation | | After irrigation | | Efficiency of application ($E_a$) % |
|---|---|---|---|---|---|
| | M.C % | Depth (mm) | M.C % | Depth (mm) | |
| 1 | 46.7 | 183.53 | 51.1 | 200.82 | 65.1 |
| 2 | 46.5 | 182.75 | 51.5 | 202.40 | 68.6 |
| 3 | 46.4 | 182.35 | 51.2 | 201.22 | 67.5 |
| 4 | 46.8 | 183.92 | 51.4 | 202.00 | 66.3 |
| 5 | 46.6 | 183.14 | 51.2 | 201.22 | 66.3 |

### 3.2 Discussion

The moisture content of the soil in the irrigation field before irrigation fell between the ranges of 46.4% and 46.8%, with an average of 46.6% which showed that the field had reasonable moisture content as of the time of this study. Also the moisture content of the field under irrigation after irrigation water was applied fell between the ranges of 51.1% and 51.5%, with an average of 51.28%, in this case the average amount of water applied was about 4.68%, showing a little increase in the moisture content of the soil in the field.

Results of water application efficiency obtained are affected adversely by some factors since efficiency of water application in the field on the farm is largely dependent on the irrigation system and on the skill of the farmer (the person managing and controlling the operation). In the evaluation of the water application efficiency through the gravimetric method of soil moisture content determination, it must be stated that in the course of collecting soil sample and how it was subsequently taken to the laboratory. The depth of water applied in irrigation is a dominant factor in analyzing efficiency of application. Even if the water is spread uniformly over the farm or field, excessive depth of application could result in low efficiency and more importantly, counter objective. To reduce this problem to a minimum, drip irrigation systems are supposed to be employed for direct application of water to the various root zones of the crops planted. The calculated average value of water application efficiency based on the results obtained was 66.76%; this value indicates that about 33.24% of water applied was lost.

## Conclusions

The information on the efficiency of water management at the point of application is considered generally of paramount importance for an effective irrigation system management. The results obtained in this investigation could attest to this assertion. Water application efficiency increased with increase in moisture content after irrigation. The values obtained were adequate and indeed a good when the available management practice are considered in terms of system operation, monitoring and evaluation.

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