STUDIA UNIVERSITATIS BABEŞ-BOLYAI
Engineering 67(1) 2022 DOI: 10.24193/subbeng.2022.1.15

Re-calibration of an automatic evaporimeter

Yahaya Olotu*, Livinus Apebuamhe Izah, Moses Eromosele Eseigbe, Reuben Ishiekwene, John Friday Ogbodo

Abstract. *A set of pre-programmed sensors and transducers, including 0.71 EAP, carbon resistor, semi-carbon conductor, IN4007, and lighting diode-4v, 60 mm amp, were used to develop and build an automatic evaporimeter for automating/self-recording evaporation rate. 10 ILP values, 8 FLP values, 150.4 and 12.3 refractive values, respectively, were used to design the evaporimeter's operating principle. The results of equipment calibration utilizing various statistical validations of voltage, calibration index, and refractive index values demonstrate high agreement with* R^2 *values of 0.999, 0.869, and 16.4 correspondingly. Every level (0.1 cm) of the instrument's time response to a step change in the water level caused by evaporation in the pan was calibrated. The voltage (v) was 225.6v, the highest evaporation value was 0.3 cm, and the refractive index was 15.0. With* $R^2 = 0.9718$ *and 0.9635, statistical validation shows that there was a significant correlation between the initial evaporation reading (IER) and the final evaporation reading (FER).*

Keywords: *Sensitivity, Water level, Calibration, Sensor, Evaporimeter*

1. Introduction

The rate of evaporation, a crucial component of climate, is influenced by the weather. Agro-meteorological research is crucial for agricultural, environmental, and water resource modeling and requires accurate measurements of environmental variables such rainfall, runoff, soil moisture, evaporation rates, and minimum and maximum temperatures. There are now just a few techniques for calculating evaporation rates. Sadly, the three reliable direct measurement techniques weighing lysimeter, Bowen ratio, and eddy flux instrumentation are unreliable for routinely measuring evaporation at meteorological enclosures. The evaporation pan has been suggested as the standard instrument for calculating crop water use by the World Meteorological Organization (WMO). The "class A" evaporation pan and the "sunken Colorado pan" are the two pans that are most well-known (Stanhill and Cohen, 2001). By measuring the evaporation loss from a water source and using empirical coefficients to tie pan evaporation to reference evapotranspiration (ETo), the pan has successfully been used to estimate reference evapotranspiration (Stanhill and Cohen, 2001). However, insufficient coverage and inconsistent instrumentation continue to hamper routine evaporation monitoring in Nigeria.

It is demonstrated that in humid areas, measurements of "class A" pan evaporation were accurate estimates of evapotranspiration when soil water was not impeding plant growth (Parmele and McGuiness, 2004). Evaporation from water surfaces or water bodies is rarely directly observed due to its nature, with the exception of relatively brief periods of time (Jones, 1992). Most frequently, evaporation from water is calculated indirectly using one or more procedures. These include mass transfer, water balance, energy balance, pan coefficients determined via pan evaporation, and combinations of other approaches (Peterson *et al.*, 1995; Robock *et al.*, 2000). The availability of data, the type or size of the water body, and the needed precision of the projected evaporation all play significant roles in determining the "optimal" technique to utilize for a given computation.

Evaporation from a standard pan, such as the "class A" pan, is measured, and the evaporation is then multiplied by a co-efficient, which is the most widely used technique in the world for measuring evaporation from tiny, shallow bodies of water. Irrigation scheduling has recently seen considerable advancements thanks to precision agricultural technology, particularly in industrialized nations where equipment for continuous climate monitoring is now available to help farmers decide how much water to apply and when to apply it. Regular measurement of evaporation rates from an automated class A tool for scheduling irrigation, an evaporation pan can be used to calculate reference evapotranspiration (Stanhill and Cohen, 2001; Robock *et al.*, 2000; Phene, 1992).

However, given Africa's cash-strapped economic realities, investing in such pricey automated systems is riskier. As a result, in this region of the world, little to no attention has been paid to using electronic level sensors to automate pan evaporimeters (Africa). The goal of this research is to develop a system for measuring evaporation that is more precise and to improve estimates of agricultural water demand. A real-time irrigation scheduling option will be made possible by the availability of an automated system, which will reduce the likelihood of human mistake in the measurement of evaporation from the pan evaporimeter. As a result, the goal of this project is to design and calibrate a low-cost electronic water level measurement device for use with class "A" pans.

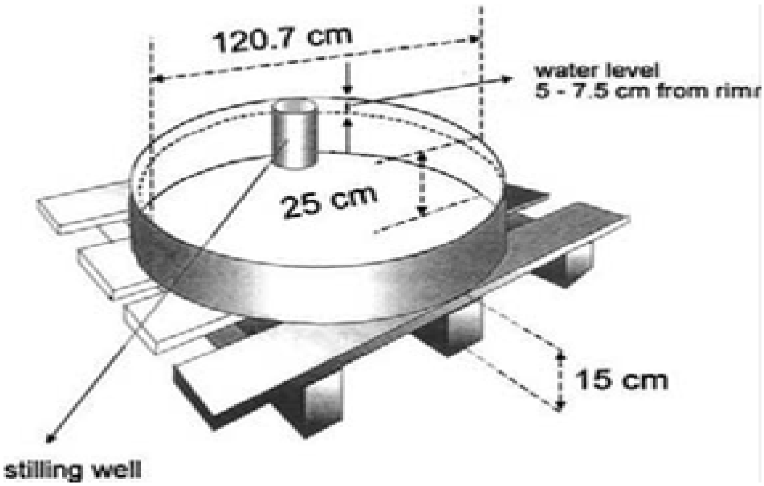
2. Materials and Methods

2.1. Description of class A pan

A Class A evaporation pan is cylindrical, measuring around 121 cm in diameter and 25 cm deep. The typical pan had a bottom that was 15 cm above the ground and was constructed of twenty-two (22) gauged galvanized metal sheets put on an open frame (Peterson *et al*., 1995; Plummer *et al*., 1995). The cylindrical United States Class A pan measures 120.7 cm in diameter and 25.4 cm deep. In order to allow air to flow underneath the pan, maintain the bottom above the level of standing water during wet weather, and make it easier to inspect the base of the pan, the bottom of the pan is elevated 3 to 5 cm above the ground level on an open-frame wooden platform. The pan is typically left unpainted and is made of 0.8 mm of galvanized iron, copper, or metal. 5 cm of the pan's bottom are filled with liquid (which is known as the reference level) Fig. 2.

2.1.1. Description of developed automated Class A Evaporation Pan

The Class A evaporation pan has a diameter and depth of 101.1 cm and 20.5 cm, respectively, and is constructed from metallic sheet measuring 3 mm gauge. The Class A pan's volume was calculated to be 0.145 m3. The stilling well, which is positioned in the middle of the evaporation pan, has a diameter of 5.5 cm and a depth of 20.5 cm. The assembled pan was set on a wooden box with a smooth surface that measured 1.09 m2 in surface area and 0.91 m in height. As seen in Fig. 1 and 2, an automatic water level sensor that monitors changes in the water level in the evaporation pan was mounted to the front edge of the pan.



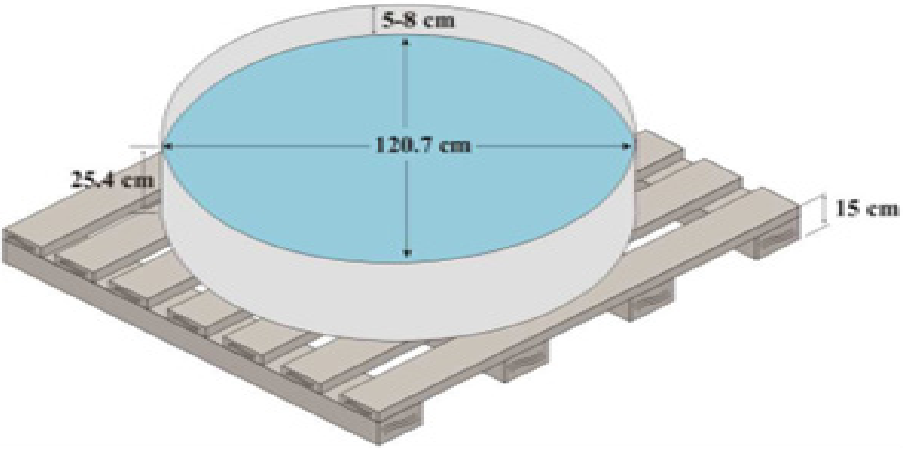


Figure 1. Class A evaporation pan

2.1.2. Instrumentation and calibration of Class A evaporation pan

The automatic evaporimeter utilizes an analog sensor that is made up of several probes (enament aluminum). The probes are in direct contact with the liquid, which causes them to change the physical variable (water) into an electrical variable when they make contact with it. The term "electrical" in this particular work refers to a change in resistance, or from 100 kΩ to infinity (Ohm), which is then utilized to activate the control line of the display unit. Each of the ten (10) units, or probes, which are made of aluminum-encased sensors, activates as soon as it touches the liquid (water). When the probe's end (a sensor or piece of aluminum) disengages from the physical variable and the control unit provides a signal to the physical variable, the process is reversed (water).

The control unit is made of:

i. A carbon resistor (100 KΩ); and

ii. A semi-carbon conductor diode (IN4007).

The light-emitting diodes used in the display unit (4v 60mini amp). The metallic conductor used for the sensor was particularly selected to prevent corrosion due to the aluminated conductor. One bulb turns on when the water level in the evaporating pan drops by 0.1 cm due to evaporation. The sensor has ten (10) graduations, or ten (10) metallic cables, with each one measuring 0.1 mm. Three lights illuminate in response to an evaporative reduction of 0.3 cm; each bulb has a refractive index value of 8.67 and is equivalent to 75.2 V. It has no dimensions, the index. The mechanism that lights up the bulb displays the outcome of the probe's contact with the physical factors at a specific time. The developed automatic evaporimeter is displayed on plate 1 in the feature (Class A pan).

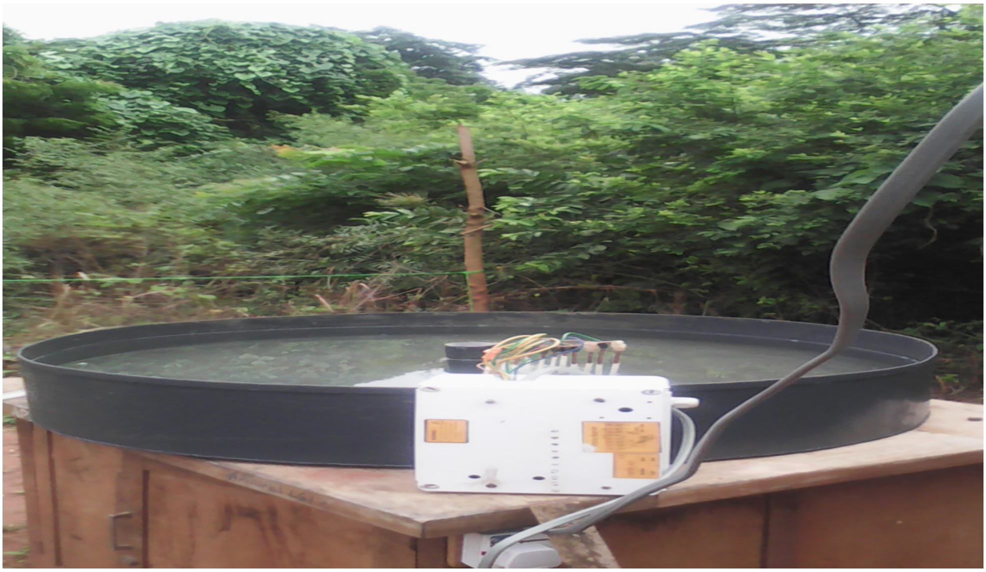


Figure 2. Developed automatic evaporimeter (Class A Evaporation pan).

2.1.3. Data analysis

The automated instrument was calibrated using the signal 1.0, power, and logarithmic components of the excel 2013 version and the generated evaporative data from the gauge and automated evaporimeters. Statistics for validation were calculated using the coefficient of determination. The estimation of the solar radiation Rs and evapotranspiration was performed using CROPWAT version 8.1. (ETo).

3. Results and Discussion

An automatic Class A evaporation pan was created and utilized to evaluate the rate of evaporation for 49 days. Voltage (v) and refractive index (RI) values were used to measure the rate of evaporation, as indicated in Table 1. As shown in Table 1, daily meteorological information including T_{max} and T_{min}, relative humidity, daylight hours, and wind speed were monitored and recorded. The maximum and minimum temperatures on the first day, June 13, 2015, were 24.5^0c and 34.2^0c, respectively. These numbers were equivalent to IER, FER, and DER values of 0.2 cm at 20.9 cm and 20.7 cm, respectively. With 10 ILP, 8 FLP, 150.4, and 12.3 refractive value simulations, this analog notion of Class A evaporation was tested. The results of equipment calibration utilizing various statistical validations are displayed in Fig. 3. With R^2 = 0.999, 0.869, and 16.4 values of the calibration index, there was strong agreement with power and logarithm, demonstrating the instrument's sensitivity to 0.1cm of evaporation. With R2 values of 0.9718 and 0.9635 for both linear and logarithmic trend analyses, respectively, statistical validation (R^2) in Fig. 4 demonstrates that there was a strong association between the initial evaporation reading (IER) and final evaporation reading (FER). It is discovered that other factors also affect evaporation rate, in addition to air temperature. On (27-06-2015), an evaporation rate of 0.3 cmday was observed at T_{min} and T_{max} temperatures of 24.50°C and 31.30°C, respectively, translating to a potential difference of 225.6V and a refractive index value of 15.0. T_{min} and T_{max} readings of 24.5 °C and 34.5°C were made on June 25, 2015, respectively. These values corresponded to an evaporation rate of 0.1 cmday, 75.2 v and a refractive value of 8.7. As a result, the accuracy of automatic Class A evaporation was determined to be ± 0.018 cm.

The crop, water, and soil model were ran using generated data from automatic evaporimeter and field meteorological measurements (CROPWAT version 8.1). The CROPWAT model's output showed that the supplied data was accurate and actual. The result in Table 1 presents that average solar radiation (Rs) and evapotranspiration (ETo) were produced. These values were 19.6MJ/m^2/day and 4.12mm/day, respectively.

Note
T_{min} = Minimum temperature ^{0}C , T_{max} = Maximum temperature ^{0}C,
$A_{ve}T$ = Average mean temperature ^{0}C ; IER= Initial evaporation value (cm),
FER= Final evaporation value (cm), DER = Difference in evaporation values (cm);
ILP = Initial lighting points; FLP = Final lighting points, V = Voltage output (v),
($\sqrt{\epsilon}$) = Refractive index, S.H = Sunshine hours, R.H = Relative humid

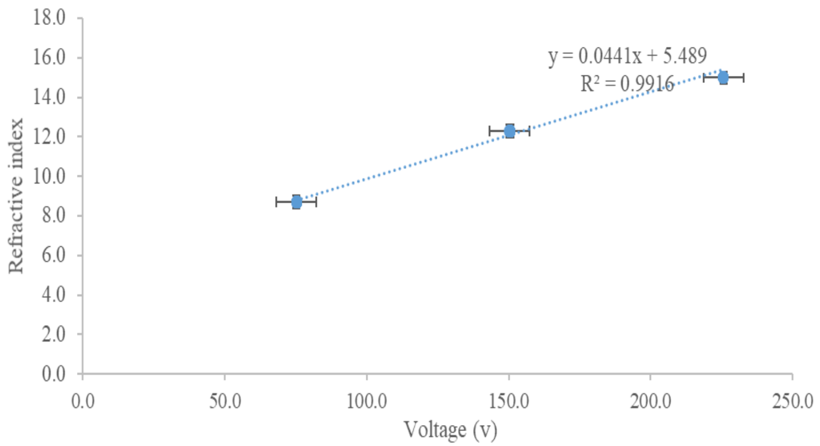


Fig.3: Calibration curve of automatic class A evaporation Pan

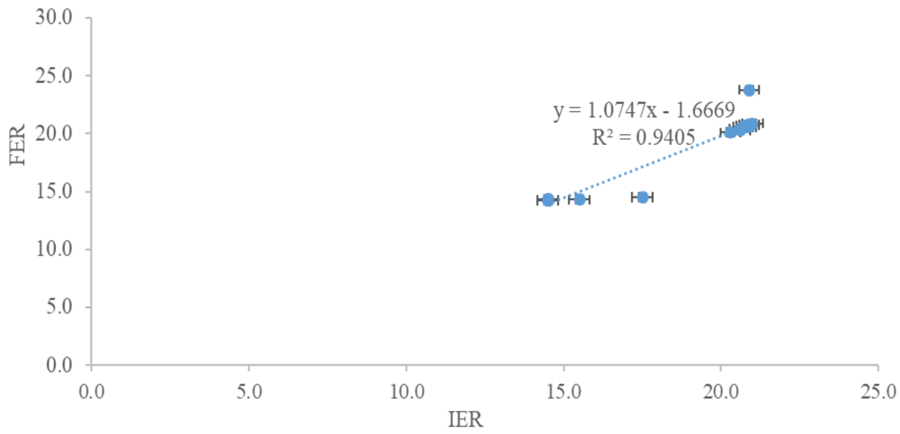


Fig.4: Simulation of daily evaporation

Table 1. Results of automatic Evaporimeter (Class A Pan)

DATE	TMIN	TMAX	TMEAN	IER	FER	DER	ILP	FLP	V(v)	S.H	RH
13\06\15	24.5	34.2	29.3	20.9	20.7	0.2	10	8	150.4	8	70.7
14\06\15	24.5	30.4	30.4	20.6	20.4	0.2	10	8	150.4	9	69.6
15\06\15	24.5	36.1	30.3	20.3	20.1	0.2	10	8	150.4	8	69.6
16\06\15	24.5	35.2	29.9	20.9	20.7	0.2	10	8	150.4	74.5	70.1
17\06\15	24.4	34.3	29.4	20.9	20.7	0.2	10	8	150.4	9	70.6
18\06\15	24.2	30.2	27.2	20.9	20.8	0.1	10	9	75.2	8.3	72.8
19\06\15	24.5	33.1	28.8	20.9	20.8	0.1	10	9	75.2	7	71.2
20\06\15	20.5	35.4	27.9	20.9	20.7	0.2	10	8	150.4	7	72.1
21\06\15	24.3	34.2	29.3	20.9	20.7	0.2	10	8	150.4	8	70.7
22\06\15	24.5	35.1	29.8	20.6	20.4	0.2	10	8	150.4	9	70.1
23\06\15	24.5	35.2	24.9	20.9	20.7	0.2	10	8	150.4	7.4	70.2
24\06\15	24.5	35	29.8	20.9	20.7	0.2	10	8	150.4	8.2	70.5
25\06\15	24.5	34.4	29.5	20.9	20.8	0.1	10	9	75.2	8.2	71.2
26\06\15	24.5	33.2	28.5	20.9	20.7	0.2	10	8	150.4	7.4	72.1
27\06\15	24.5	31.3	27.9	20.6	20.3	0.3	10	7	225.6	8	71.7
28\06\15	24.5	32.1	28.3	20.7	20.6	0.1	10	9	75.2	8.1	71.1
29\06\15	24.5	33.2	28.9	20.9	20.8	0.1	10	9	75.2	7.5	71.7
30\06\15	24.5	32.1	28.3	20.8	20.6	0.2	10	8	150.4	8.3	72.7
1\07\15	23.2	31.4	27.3	20.9	20.7	0.2	10	8	150.2	7.4	72.1

DATE	TMIN	TMAX	TMEAN	IER	FER	DER	ILP	FLP	V(v)	S.H	RH
2\07\15	24.5	31.3	27.9	20.8	20.7	0.1	10	9	75.2	7.4	72.1
3\07\15	20.5	32.1	26.3	20.8	20.7	0.1	10	9	75.2	8	73.7
4\07\15	24.5	32.3	28.4	21.0	20.9	0.1	10	9	75.2	7.5	71.6
5\07\15	20.5	34.5	27.5	20.8	20.7	0.1	10	9	75.2	7.3	72.5
6\07\15	24.5	33	28.8	20.9	20.8	0.1	10	9	75.2	7.4	71.2
7\07\15	20.5	33.3	26.9	20.9	23.8	0.1	10	9	75.2	8.3	72.1
7\07\15	24.5	34.2	29.4	20.9	20.7	0.2	10	8	150.4	7.5	70.6
9\07\15	24.5	33.5	29	20.9	20.8	0.1	10	9	75.2	8	72.1
10\07\15	24.2	32.4	28.3	20.9	20.8	0.1	10	9	75.2	8.2	71.7
11\07\15	24.5	34.3	29.4	20.8	20.7	0.1	10	9	75.2	8.3	70.6
12\07\15	24.5	33.1	28.8	20.9	20.8	0.1	10	9	75.2	8.5	71.2
13\07\15	24.5	32.4	28.5	20.8	20.6	0.2	10	8	150.4	8	71.5
14\07\15	24.5	34.1	29.3	20.9	20.7	0.2	10	8	150.4	8.3	70.7
15\07\15	24.3	33	28.7	20.9	20.8	0.1	10	9	75.2	7.5	71.3
16/07/2015	24.2	33.2	28.9	20.9	20.8	0.1	10	9	75.2	8.5	71.1
17/07/2015	34.5	32.3	28.4	20.9	20.7	0.2	10	8	150.4	7.5	71.6
18/07/2015	24	33.3	28.2	20.9	20.8	0.1	10	9	75.2	7.4	71.8
19/07/2015	24.2	31.5	27.9	20.9	20.8	0.1	10	9	75.2	8.2	72.1
20/07/2015	23.5	30.2	26.9	20.9	20.7	0.2	10	8	150.4	8.2	73.1
21/07/2015	24.5	33.1	28.8	20.9	20.8	0.1	10	9	75.2	8.2	71.2
22/07/2015	24	32.3	28.2	20.9	20.7	0.2	10	8	150.4	7.5	71.8
23/07/2015	23.2	31.2	27.2	20.9	20.8	0.1	10	9	75.2	7.5	72.8
24/07/2015	20.2	35.2	27.7	17.5	14.5	2	10	8	150.4	8	72.3
25/07/2015	27	35.3	31.2	14.5	14.2	0.3	10	7	225.6	8.2	68.8
26/07/2015	20	35	27.5	14.5	14.2	0.3	10	7	225.6	8.1	72.5
27/07/2015	26	31	28.5	14.5	14.2	0.3	10	7	225.6	7	71.5
28/07/2015	24.2	31.3	27.8	14.5	14.3	0.2	10	7	225.6	7.2	72.2
29/07/2015	23.3	35.4	29.4	15.5	14.3	0.2	10	8	150.4	7.5	70.6
30/07/2015	24.5	25.2	29.9	14.5	14.3	0.2	10	8	150.4	7.2	70.1
31/07/2015	20.1	34.3	27.2	14.5	14.3	0.2	10	8	150.4	7.3	72.8

Source: Field study, 2015

4. Conclusion

Due to global climate change, the expensive and time-consuming direct measuring methods used to determine crop water use cannot be employed in a safe manner in the upcoming years. The methods for estimating evapotranspiration using meteorological data will be more and more crucial. In irrigation scheduling, water resource modeling, and management, the Pan evaporation method works well for obtaining findings quickly. Convectional evaporimeters must contend with problems including poor upkeep that causes inaccuracies because of leaks, the growth of algae in the water, an improper water level, and weed growth. The created automatic Class A evaporation pan measures the evaporation rate using enament aluminum probes and a self-recording system.

The measurement precision of the instrument is 0.018 cm, the evaporation depth is 0.1 cm, the voltage (V) value is 75.2 V, and the refractive index value is 8.7 V, respectively. A physics-deterministic model would be run using the instrument's exact and accurate readings/data to address issues with river flow regime, water and soil erosion management, and precision agriculture systems.

Acknowledgment. The authors equally contributed to this study. The also thank Engr.(Dr.) Olotu Yahaya for his technical contributions and review.

References

[1] Purvis J.C., Pan evaporation records for the South Carolina, *Water International,* 19, 2006, pp. 30–34.

[2] Stanhill G., Cohen S., Global dimming: a review of the evidence for a widespread and significant reduction in global radiation with discussion of its probable causes and possible agricultural consequences, *Agricultural and Forest Meteorology,* 107, 2001, pp. 255–278.

[3] Linacre E.T., Estimating U.S. class A pan evaporation from few climate data, *Water International,* 19, 1993, pp. 5–14.

[4] Jones C., Empirical method of estimating evapotranspiration, *Atmospheric Research,* 40, 1992, pp. 87–90.

[5] Peterson T.C., Golubev V.S., Groisman P.Y., Evaporation losing its strength, *Nature,* 377, 1995, pp. 687–688.

[6] Plummer N., Lin Z., Torok S. Trends in the diurnal temperature range, *Atmospheric Research,* 40, 1995, pp. 60–65.

[7] Robock A., Konstantin V.Y., Srinivasan G., Entin J.K., Hollinger S.E., Speranskaya N.A., Liu S.X., Namkhai A., The global soil moisture data bank, *Bulletin of the American Meteorological Society,* 81, 2000, pp. 1281–1299.

[8] Parmele Y., McGuinness O., Comparison of measured and estimated daily potential evapotranspiration on humid region, *Atmospheric Research,* 40, 2004, pp. 77–84.
[9] Phene C.J., Real-time irrigation scheduling of cotton with automated pan evaporation Australia since 1951, *Atmospheric Research,* 37, 1992, pp. 79–86. evaporation pans. 16: 61-67 Natural Resources, South Carolina State Climatology Office; Vol (3); pp. 10-17

Addresses:

- Dr. Engr. Yahaya Olotu, Auchi Polytechnic, Department of Agricultural & Bio-Environmental, Auchi, Edo State, Nigeria, olotu.abiodun@yahoo.com
  (*corresponding author)
- Dr. Engr. Livinus Apebuamhe Izah, Auchi Polytechnic, Department of Mechanical Engineering, Auchi, Edo State, Nigeria
- Engr. Moses Eromosele Eseigbe, Auchi Polytechnic, Department of Mechanical Engineering, Auchi, Edo State, Nigeria
- Engr. Reuben Ishiekwene, Delta State Polytechnic, Department of Electrical Engineering, Ogwashiku
- John Friday Ogbodo, Kogi State Polytechnic, Department of Metallurgy, Lokoja, Kogi State