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Lysimetric Analysis of the Influence of Organic Materials on Evapotranspiration and Coefficient of Maize Crop in Maiduguri, Borno State

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Abstract: *Drainage lysimeter is the one of the standard method for directly measuring crop evapotranspiration (ETc). The determination of crop water requirement is one of the key parameters for precise irrigation scheduling especially in regions with limited water resources. The study was to determine the influence of organic materials on evapotranspiration of maize crops in semi-arid region of Maiduguri, Nigeria. A drainage type lysimeter of 0.6m height, and 0.3 diameter with cross-sectional area of 0.85m² was used. The organic materials used were; Moringa olifera leaves and Groundnut Haulm respectively, were ground and incorporated into the soil at tonnage of 4.5 t/h. The organic materials (treatments) were laid in Randomized Complete Block Design (RCBD). For consistency water application, an irrigation interval of 4 days was maintained. Furthermore, accumulated measured ETc for maize all stages of growth was found highest in moringa leaves treatment with ETc of 342 mm respectively. However, moringa treatment had significantly ($p<0.05$) influence on the growth parameters at all stages of growth, crop coefficient and yield of the crop studied than any other organic materials. Nevertheless, the highest average maize crop coefficient values of 0.40,1.09 1.3 and 0.7, at all stages of growth was induced by moringa. Likewise, regression analysis revealed that cob length and number of seed per cobs is the highest independent variable influencing the yield of the maize than any other yield parameter experimented with regression coefficients of values of 73.40, 506.40, and 437.25, respectively. In addition, the crop evapotranspiration values of maize crops using the lysimeter for four stages of growth were 18.8, 88, 141.2 and 88 with seasonal total ETc of value of 336mm, respectively. Thus, implies that the applicability of moringa olifera as treatment is a good representation of improving maize crop evapotranspiration to semi-arid region with sandy soil.*

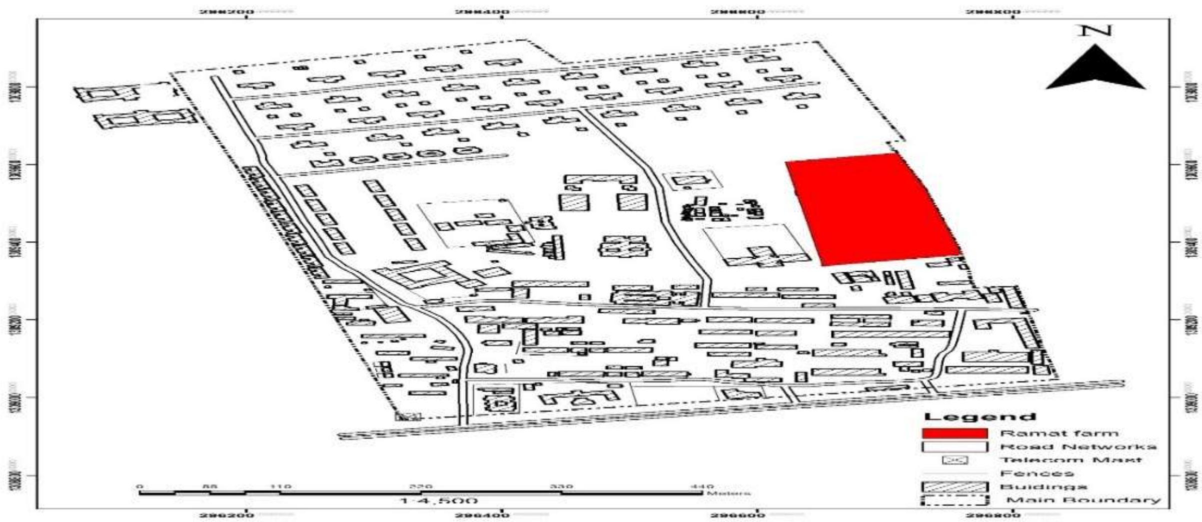
Key words: *Maize; Evapotranspiration; Lysimeter; Organic Materials and Coefficient*

1.0 Introduction

Agricultural water users must plan an annual water budget in semi-arid and arid region lands and area where water usage is regulated due to ecological protection programs, limited resources and competitive demand (Barrett, 2005). Therefore, the Knowledge of crops evapotranspiration (ETc) is important in scheduling irrigations, optimizing crop production, modelling crop evapotranspiration and crop growth. The ability to measure, estimate, and predict cereal crop ET and water requirements can result in better satisfying the water needs of crops and improving water use efficiency in arid and semiarid regions. Lysimeter are the most reliable research tool for direct evaluation of evapotranspiration (Lu *et al.,* 2005) The knowledge of water requirement at various stages of crop growth through the use of lysimeter makes it possible to manage rainfall, even with its inherent uncertainties in amount, duration and distribution, to the best advantage of the crop (Martínez *et al*., 2004). Irrigation plays an important role in food production globally, irrigation is the supply of water to agricultural crops by artificial means, designed to permit farming in arid region and to offset the effect of drought in semi-arid region and even in areas where total seasonal rainfall is adequate or average (FAO,2011). Maize (*Zea mays*) is a tropical crop largely grown in various parts of northern- Nigeria, it performs well when irrigated or rain fed with about 600-900 mm of rainfall per annum at a temperature range between 20^{o}C and 25^{o}C (Arora 2004).According to (Bashir *et al.,* 2006) the seasonal irrigated pearl maize ETc values estimated to be 596 mm and the estimated Kc values at the initial, development, midseason and late season stages were 0.62, 0.85, 1.15 and 0.48, respectively, using the energy balance model. Again, according to (Piccinni e*t al.,*2009), hybrid maize was grown between 2006 and 2008 in crop lysimeter fields, which were used in the determination of Kc. They found seasonal accumulations ETc in 2006, 2007 and 2008 with values of 491, 533 and 521 mm, respectively, However, elevation of organic material level in the soil can promote increased crop yield, stored moisture and enhancing evapotranspiration especially in sandier soil by management of cation exchange avoiding major losses by leaching (Yanfei *et al*., 2006). In addition, organic material is an important way to provide nutrient to plant and may promote greater absorption efficiency resulting in productivity gain (Sendiyama *et al.,*2009). Moringa Olifera is a tropical crop, grown for its nutritional and medicinal purposes. According to (Foidl *et al*., 2001). Moringa has been reported to possess wide adaptations and high nutrients composition in its biomass (Bosch, 2004). Furthermore, groundnut haulm has most of the qualities of mulching materials, but is not commonly used in the semi-arid region of Africa (maduka, 2011). Most crops grow best in soil with organic matter content between 2 and 5 percent (Pennsylvania. 2009). Therefore, the current study is undertaken to determine the influence of organic materials on maize crop evapotranspiration and coefficient in semi-arid region of Maiduguri North-Eastern Nigeria.

2.0 Experimental and Site Description

The experiment was conducted at the Teaching and Research Farm, of the Ramat Polytechnic, Maiduguri, in the Sudano-Sahelian region of northern Nigeria. The site lies between latitude 11^{0}5 N and longitude 13^{0}09E (Kyari *et al*., 2014). The area is about 335m above sea level and lies within the lake Chad Basin formation, which is an area formed as a result of down –warping during the Pleistocene period (Waziri, 2007).



2.1 Materials and Methods

2.1.1Treatment and Experimental Design

The experimental factors to be considered in this studies are maize crop and organic materials. The organic materials were two level, namely Moringa Olifera leaves, Groundnut haulms and control. These factors were combined and replicated three times to form a total of 12 treatments which were laid in a Randomized Complete Block Design (RCBD). (Figure 3.1) Essentially, in each plot was a lysimeter in which crop was planted and organic material were incorporated.

2.1.2 Lysimeter Installation

The experimental site was15m x 15m. The selected area was divided into 3 Plots of 14m x 4m each with a foot path of 1.5m in between the plots. Subsequently, the entire land area was fumigated manually to prevent the crops from pest attack. Drainage type lysimeter of 0.6m height, and 0.3 diameter with cross-sectional area of 0.85m2 were used for this study. A plastic container (5 liters) was placed at 1m away from the lysimeter to serve as drainage collector. However, 0.02m (2cm) diameter plastic pipe was used to link between the lysimeter and the drain collector. The Installation was accomplished by used of backhoe, forklift, hand shovels, and hand tools. An order of returning excavated soil for the lysimeter. "last out first in and first out last in" was used to maintain same natural soil structure or arrangement as suggested by Shukla *et al*., (2007). Furthermore, the lysimeter were set into the soil pebbles and wire mesh was placed at the bottom of the lysimeter to a depth of 5cm in order to facilitate easy drainage and help in preventing blockage of the drain. The organic materials used for this study were moringa Olifera leaves, groundnut haulm and a control plot were grown and incorporated into the soil at 0.45kg/m2 tonnage to a depth of 8 inch beneath the soil for the all experimental unit, the crop was irrigated as per the design of the treatments. Measured quantity of water was applied ensuring drainage. Soil moisture was measured before each irrigation. Since the experiment was carried out in dry season no rainfall part was considered and only change in stored soil moisture during the period under consideration were subtracted from the applied water to obtain crop evapotranspiration

(ET_c). Data on growth and yield parameters were recorded and subjected to Analysis of Variance (ANOVA) using STAISTIX 8.0 computer package. Duncan's New Multiple Range Test was used to separate the significant means at 5% level of probability.

2.2 Estimation of Crop Evapotranspiration (ETc) using lysimeter

The determination of crop evapotranspiration using lysimeter was achieved using Equation (1) below as suggested by (Sharma 1995). However, the moisture available in the soil at the root zone of the crops in each lysimeter was estimated using speedy moisture meter. Nevertheless, the difference between water applied and water drained was determined using measuring cylinder.

$$ET_c = R_w + I_w - QD \pm \Delta S \qquad (1)$$

Where: ET= Evapotranspiration (mm/day), Rw = Rainfall Water (mm) Iw = Irrigation Water (m^3) QD=Quantity of water drained Δs=Surface & Subsurface changes in storage difficulties Involved

2.3 Estimation of Crop Coefficient

Crop coefficient was determined at growth stages of the crops using empirical relation recommended by (Allen *et al*., 1994) shown in equation (2).

$$K_c = \frac{ET_c}{ET_o} \qquad (2)$$

Where, Kc is crop coefficient (-), ETc is crop evapotranspiration in (mm/day) was estimated as stated in 2, ET_o is reference evapotranspiration in (mm/day) was estimated using pan method as mentioned in shown in equation (3)

$$ET_o = K_{pan} \times E_{pan} \qquad (3)$$

2.4 Yield and Yield Attribute
The yield parameters at the fully maturity, the cob length was measured using meter rule and the mean was recorded for each treatment in (cm). Number of panicle per plant was counted and the mean values was recorded. The panicle from each lysimeter in the experiment units were threshed, seeds were counted, and the average seed number per head was recorded.

2.5 Statistical Analysis
All data collected in the study were subjected to Analysis of Variance (ANOVA) as described by (Gomez and Gomez, 1984) using Statistics 8.0 package. The difference between treatments means were separated using least significant difference (LSD).

3.0 RESULTS AND DISCUSSION

3.1 Influence of Organic Materials on Crop Evapotranspiration (ETc)

The experimental results obtained on influence of organic materials on crop evapotranspiration of maize was presented in an internationally recognized growth stages

Initial (10 DAS), development (35 DAS), middle (60 DAS) and late season (80DAS) as shown in Table 1. The organic materials used as treatment had significantly ($p<0.05$) influenced the crop evapotranspiration of maize. The highest ETc values of (20.1mm and 86.2) were recorded between moringa leave and groundnut haulm at initial and late stage of development, it was closely followed by other treatments used. At development and middle stages of growth, the uppermost ETc values of (90.5 mm and 150.7 mm) were found between moringa leaf and control plot respectively. Similarly, at late stage of growth, the highest ETc value of (86.2 mm) was remarkably induced from moringa and it was narrowly followed by both groundnut haulm and control plots experimented with corresponding ETc values of (78.7 and 78.1), respectively. The evapotranspiration ETc obtained in this study is also similar to those reported by (Adeniran et al., 2010), for sub-Saharan and is in line with the findings of (Meysam, 2015). For more clarification of the result see Figure 2.

Table 1: Influence of organic materials on evapotranspiration (ETc) of maize crop at different stages of growth (mm)

Treatments	Initial	Development	Middle	Late
Moringa leave	19.2b	88.1b	128.1c	86.2a
Groundnut haulm	20.1a	75.3c	141.0b	78.7b
Control	19.3c	90.5b	150.7a	78.1b
SE±	3.895	4.080	5.071	2.517

Means within a column followed by same letter(s) are not significantly different at 5% probability level

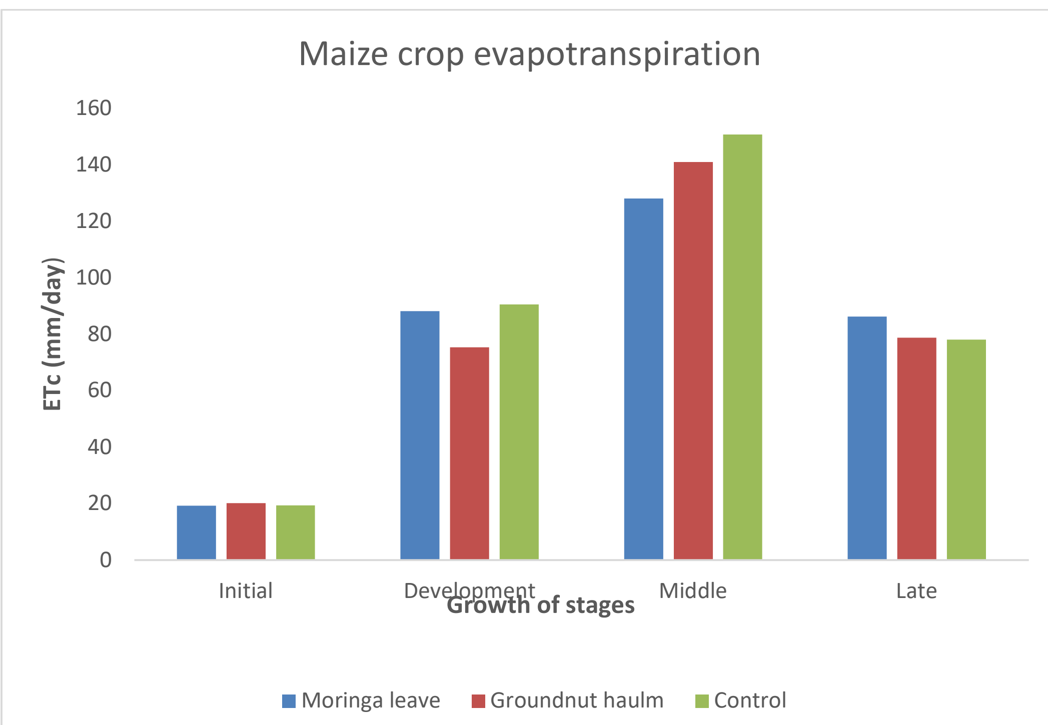


Fig 2: Plots on Influence of organic materials on evapotranspiration (ETc) of maize

3.2 Influence of Organic Material on Stage –Wise Crop Coefficient (Kc).

Table 2. Shows the influence of organic materials on crop coefficients of maize at different stages of growth in the experimented farm. The organic material used as treatment had significantly ($p<0.05$) influenced the Kc of the maize. The highest Kc values of 0.43, and 1.20 at initial and development stages was recorded from moringa leave, at same stages was closely followed by groundnut haulm with corresponding Kc values of 0.43 and 0.93, respectively. While, at the middle and late stages of growth, groundnut haulm has the best crop coefficient value than all other organic material experimented. However, the least was recorded with the control plot. The changed in Kc could be attributed to the seasonal variation of leaf area which is in line with the findings of Zhang et al (2005). For more detail see figure 1.

Table 2: Influence of organic materials on stage –wise crop coefficient (Kc).

Treatments	Initial	Development	Middle	Late
Moringa leave	0.43[a]	1.20[a]	1.09[c]	0.77[a]
Groundnut haulm	0.43[a]	0.93[b]	1.53[a]	0.73[a]
Control	0.36[b]	1.13[b]	1.27[bc]	0.60[ab]
SE±	0.145	0.211	0.198	0.314

Means within a column followed by same letter(s) are not significantly different at 5% probability level

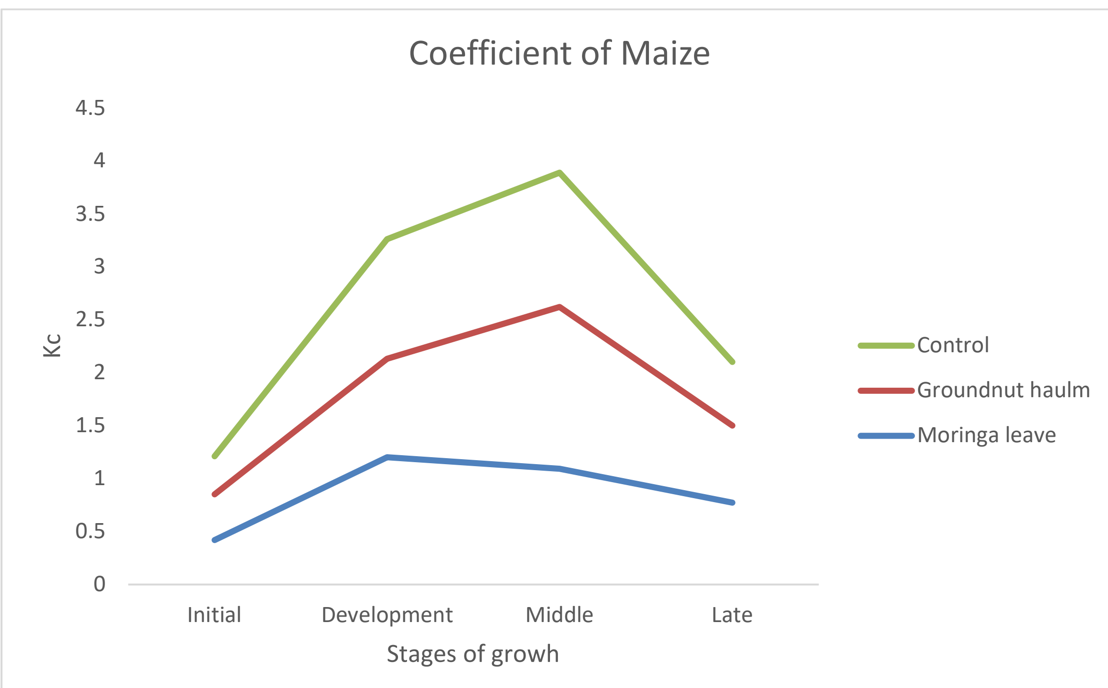


Figure 3: shows the influence of organic material on stage-wise crop evapotranspiration (ETc) for Maize crop

3.3 Influence of Organic Material on Yield Parameters and Yield of maize

Table 3. Shows the yield and it attributes as influenced by the organic material used as treatment in the study area. Treatments used had significantly ($P<0.05$) influenced the yield and its parameters of maize crop as shown in Table 4.11. The maximum cob length and cob diameter were recorded with moringa leaves 23 cm, and 18.3 cm, respectively. Closely followed by groundnut haulm with 20.3 cm, and 17.6 cm respectively. While the least cob length and cob diameter of the grain were observed in groundnut haulm and control lysimeter. Similarly, highest number of cobs per plant of 4 were found with moringa leaves and it was closely followed by groundnut haulm, while, the least was recorded in control plot. The findings is in line with Zhang *et al.* (2005). In addition, treatments had also significantly induced the grain yield of the maize crop. Highest grain yield 5.1 t/ha with (578) total number of seed per cob was achieved from moringa leaves, closely followed by groundnut haulm with corresponding yield and number of seed per cobs of 4.7 t/ha and 3.5 t/ha and 511 and 437, respectively. While the least grain yield was harvested in control lysimeter. This could be attributed to the nutrient content of the organic materials which have apparently boosted growth and development of the plant. The findings tallied with Zhang *et al.* (2008) who observed highest grain yield of maize while using weighing lysimeter with the used of straw as treatment than control plot.

Table 3: Influence of organic materials on yield and yield parameters of maize

Treatment	Cob/panicle length (cm)	Cob/panicle diameter (cm)	Number of cob/panicle per plant	Number seed per cob/panicle	Cob weight (Kg)	Yield (kg/ha)
Maize						
Moringa leave	23.0[a]	18.3[a]	4[a]	578[a]	0.8333[a]	5.146[a]
G. haulm	18.9[c]	16.5[c]	3[ab]	437[bc]	0.3736[c]	3.540[c]
Control	17.1[d]	16.0[c]	2[c]	324[c]	0.2833[c]	2.591[d]
SE±0.567	1.250	2.3149	1.997	59.152	0.128	191.73

3.4 Regression Studies (Sensitivity Coefficient)

Table 4. Shows the regression analysis on maize grain yield and its attributes to determine R^2 relation, as well as the most sensitive coefficient among the dependent variables that influences the maize grain yield. maize crop exhibited R^2 of 0.98%indicating high positive relationship, the highest regression coefficient value of 506.4069 was influenced by cob length, closely followed by number of seed per cobs with regression of 0.990536, while cob

diameter exhibited negative regression of -222.818 which indicated less influence on the yield of the maize.

Table 4. Multiple regression analysis among the yield and growth parameters.

Regression Coefficients	
Independent Variables	Maize crop
Intercept	-2890.3
Cob /panicle length	506.4069
Cob/panicle diameter	-222.818c
Number of seed per cobs/panicle	0.990536
R-square	0.98%
Multiple R^2	0.57%
Adjusted R^2	0.13%
Standard error	1.24

3.5 Conclusion and Recommendations

3.5.1: Conclusion:

The research analyzed the influence of organic materials on crop evapotranspiration of maize, to determine its influence on the crop. The study employed statistical technics including analysis of variance (ANOVA) and Nash- Sutcliffe efficiency (NSE) and concluded as follows:

(i) Analysis of variance (ANOVA) showed a significant difference between the treatments used (organic materials). Moringa Olifera has the highest influence ET_C of all crops experimented

(ii) The highest grain yield of 5.1t/ha, respectively for maize was recorded with moringa olifera leaves. Equally regression analysis revealed that panicle length and number of seed per cobs/panicle is the highest independent variable influencing the yield of the maize than any other yield parameter and most often was influenced by moringa than other treatment.

3.5.2 Recommendations

(i) Since this experiment is season study in a single environment, further research over seasons are required so as to develop reliable values.

(ii) The experiment should be repeated in similar agro-climatic condition in order to confirm the findings.

References

Allen, R.G., L.S. Pereira, D. Raes and M. Smith, 1998. Crop evapotranspiration. Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No. 56. FAO, Rome, Italy, Pp. 469.

Bashir, M.A., T. Hata, A.W. Abdelhadi, H. Tanakamaru and A. Tada, 2006. Satellite-based evapotranspiration and crop coefficient for irrigated sorghum in the Gezira scheme, Sudan. *Journal of Hydrology and Earth System Sciences,* 3: 793 – 817.

Chiroma, A. M. (2004). Effects of land configuration and wood-shavings mulched on soil properties, yield and water use of sorghum. Unpublished Ph.D.Thesis, University of Maiduguri.23(8-90:232-34

Chiroma, A. M., Alhassan, A. B. and Bababe, B. (2005). Physical properties of a sandy loam soil in northeastern Nigeria as affected by tillage and stubble management. Nigerian Journal of Tropical Agriculture, 6:115-121.

Dalhart, M (2005) Lysimeter design, construction, and instrumentation or assessing evaporation from a large undisturbed soil monolith. Appl Eng Agric, 14:303–308.

Dalorima L (2002) Effects of Different organic matters on the Growth Performance of Amaranthus in Maiduguri International Research Journal of Agricultural Science and Soil Science, 3(6):240-339.

De Rouw, A. and J.L. Rajot, (2004): Soil organic matter, surface crusting and erosion in Sahelian agricultural systems based on manuring and fallowing. Agric. Ecosyst. Environ. 104:263–276.

Dibal, J.M (2002). Dersitification in Nigeria. Causes, effect and review of control measures. University of Maiduguri, faculty of engineering seminar series, 2(1):59-74.

Dibal.,J.M., Dauda, A. and Umara, B. (2006). Irrigation and society.A review, University of Maiduguri Faculty of Engineering Seminar Series, 4(1): 52- 61.

Egharevba PN. (1999) A correlation factor in the estimation of leaf area in millet. Samara Agricultural Newsletter;10 (2):84-85.

Ejieji, C. J. (2011). Performance of Three Empirical Reference Evapotranspiration Models under Three Sky Conditions using two Solar Radiation Estimation Methods at Ilorin, Nigeria. Agricultural Engineering International: CIGR Journal.

El-Badawy, M and El.M., (2006). The relative contribution of yield components by using specific statistical techniques in corn. Annals of Agric. Sci., Moshtohor, 44(3): 899-909.

Ezeaku et al (2004). Estimation of crop Water Requirement from Climate and Soil Data for Maize Production in Two SE Nigeria locations, a paper presented at the Annual Conference of the Soil Science society of Nigeria pp 11-23.

FAO (1995). Production Yearbook Vol. 49. Food and Agriculture Organization, United Nations, Rome, Italy.

FAO (2006). World reference base for soil resources 2006. By: IUSS working group. World Soil Resources Reports 103. Rome, Italy

FAO (2010). Soil Biota and Biodiversity" The "Root" of Sustainable Development" ftp.fao/010/i0112e07.pdf, February, 2010.

FAO 2002. Crop Water Requirements and Irrigation Scheduling. Developed by: A.P. Savva and K. Frenken. FAO Irrigation Manual Module 4. Harare, Zimbabwe.

FAO, (1998). Agriculture, Food and Nutrient for Africa: A Resource Book for cooperate Document repository, 2: 145- 175.

FAO, (1998). Agriculture, Food and Nutrient for Africa: A Resource Book for cooperate Document repository, 2: pp. 145- 175.

FAO, 2000. Crop evapotranspiration – Guidelines for computing crop water requirements, By: R. Allen, L. Pereira, D. Raes, M. Smith, Irrigation and drainage paper 56.

FAO, United Nations, 2001, Expert consultation Italy, on revision of FAO methodologies, 28-31 May for crop water requirements, Annex V. Rome.

Foildl, N., and Paul, R. (2001). Moringa olifera. In: The Encyclopedia of fruit and nuts (pp 509 – 512). CABI, Oxfordshire, UK:

Gomez KA, and Gomez AA (1984). Statistical Procedures for Agricultural Research. 2nd edition. John Wiley and Sons Inc., New York. pp 75-165.

Gomez KA, Gomez AA (1984). Statistical Procedures for Agricultural Research. 2nd edition. John Wiley and Sons Inc., New York. pp 75-165.

Govinda,B .(2012). Estimation of Potential Evapotranspiration and Crop Coefficient of Maize at Rupandehi District of Nepal. International Journal of Agricultural Management & Development (IJAMAD) Available online on: www.ijamad.com ISSN: 2159-5852 (Print) ISSN:2 159-5860 pp1-4.

Grema, A. K. and Hess, T. M. (1994). Water balance and water use of pearl millet –cowpea intercrops in northeast Nigeria.Journal of Agricultural Water Management, 26: 169-185.

Ha and Ha, (2011). Crop coefficient: The key to improving crop yield Journal of Irrigation, 7: 231 - 246. Hargreaves GH, Samani ZA. Estimating potential evapotranspiration. Tech. Note. J. Irrigation and Drainage Eng; 1982.

Hill, G.R, (1991). Assessing explotion in Mediterranean aquifers using stability condition analysis. Ecol. Model, 218:256-260.

Hirasawa, T., (1995). Water relations in plants. In: Matsuo, T., Kumazawa, K., Ishii, R., Ishihara, K., Hirata, H. (Eds.), Science of the Rice Plant, vol. two, Physiology. Food and Agriculture Policy Research Center, Tokyo, pp 434-460.

Horticulturae, 4 Jan. 2007, 111(2): 128-132.

Houshang G, Fatemeh M, Sajad, and Davoud A 2015 Evaluation of a Few Evapotranspiration Models Using Lysimetric Measurements in a Semi-Arid Climate Region International Journal of Plant & Soil Science 5(2): 100-109, 2015; Article OIJPSS.2015.064 ISSN: 2320-7035

Howell, T.A., 2001. Enhancing water use efficiency in irrigated agriculture. Journal of Agronomy, 93:281-289.

Igbadum, H.E., Tarimo, A.K., Salim, B.A and Mahoo, H. F(2007). Evaluation of selected crop water production functions for an irrigated maize crop. Agric. water manage, 94:1-10.

Irmak, S., Haman, D.Z., and Bastug, R., (2009). Determination of crop water stress index for irrigation timing and yield estimation of corn. Agron. J. 92, 1221–1227.

Islam, M. S. and Hossain2, M. A. (2010). Determination of crop co-efficient of hybrid maize by lysimeter study . Bangladesh J. Agril. Res. 35(1) : ISSN 0258-7122, pp 77-82.

Iyanar, K., Gopalan, A. and Ramasamy, P. (2001). Correlation and path analysis in sorghum. Ann. Agric. Res., 22(4): 495-497.

Jensen, M.E., (1990). Water Consumption by Agricultural Plants. In: Kozlowski, T.T. (Ed.), Water Deficits and Plant Growth: II. Academic Press, Inc., New York, NY, Pp. 1–22.

Jensen, M.E., Burman, R.D., and Allen, R.G., (1990). Evapotranspiration and irrigation water requirements, ASCE Manuals and Reports on Engineering Practice No.70. ASCE, New York, NY.

Johnson, M.A, 2000. Grain Millet Production Handbook. Kansas State University, Manhattan, Kansas. Pp. 1 – 32.

Jones, H.G. (2004). Irrigation scheduling: advantages and pitfalls of plant based methods. Journal of Experimental Botany, 55:2427-2436,

Kang, S., B. Gu, T. Du and J. Zhang, (2008). Crop coefficient and ratio of transpiration to evapotranspiration of winter wheat and maize in a semi humid region. Chinese Journal of Agricultural Water Management, 59: 245-251.

Katerji, N., Mastrorilli, M., van Hoorn, J.W., Lahmer, F.Z., Hamdy, A., and Oweis, T., (2009). Durum wheat and barley productivity in saline–drought environments. European Journal of Agronomy. 31, 1-9.

Klocke NL, Todd RW, Hergert GW, Watts DG, Parkhurst AM (1993) Design, installation, and performance of percolation lysimeters for water quality sampling. Trans ASAE, 36: 429–435.

Ko J, Piccinni G, Marek T, Howell T (2009). Determination of growth-stage-speciffic crop coefficients (Kc) of cotton and wheat. Agric. Water Manage. 96:1691-1697. http://dx.doi.org/10.1016/j.agwat.2009.06.023

Koe J, Piccinni G, Marek T, and Howell T (2009). Determination of growth-stage-specific crop coefficients (Kc) of cotton and wheat. Agric. Water Manage. 96:1691-1697. http://dx.doi.org/10.1016/j.agwat.2009.06.023

Koy J, Toyin R, Miguel, Oguntunde, Philip G, and Ayodele E (2014).Greenhouse evapotranspiration and crop factor of Amaranthus cruentusgrown in weighing lysimeters. African Journal of Agricultural Research Vol. 10(34), pp. 3453-3461, 20

Kyari Z., Dalorima L.T, Bunu A., and Mohammed T. (2014)Effects of Different Mulching Materials on the Growth Performance of Okra in Maiduguri International Research Journal of Agricultural Science and Soil Science, 4(8):145-149.

Kyari Z., Dalorima L.T, Bunu A., Mohammed T. (2014).Effects of Different Mulching Materials on the Growth Performance of Okra in Maiduguri International Research Journal of Agricultural Science and Soil Science, 4(8):145-149,

Maina MM, Amin MSM, Aimrun W, Asha TS (2012) Evaluation of different ETo calculation methods: A Case study in Kano state, Nigeria. Philipine Agric Scientist, 95(4):378–382.

Malone RW, Bonta JV, Stewardson DJ, Nelsen T (2000) Error analysis and quality improvement of the Coshcton weighing lysimeters. Trans ASAE, 43: 271–280. Manuscript No. 1673. Vol. 13(3). Pp1-21.

Uguru, M.I. (1996). Crop Production Tools, Techniques and Practice. Published by Fulladu Publishing Company B. Umeano Estate Nsukka, Nigeria. pp 231-241

Vaughan, P.J., Trout, T.J., and Ayars, J.E., (2007). A processing method for weighing lysimeter data and comparison to micrometeorological ET 0 predictions. Agric. Water Manag. 88, 141–146.

Venkantramanen MV (2013). Effect of industrial and organic wastes on groundnut in typicustifluvent soil. Am. Agric. Res. New series. 22(3): 436-438.

Viola G. M.,Ganesh S., Reddy S. and Kumar C.V.S. (2003). Studies on correlation and path coefficient analysis of elite baby corn (Zea mays L.). Indian Prog. Agri. 3(1-2): 22-25.

Walker TH, Schneider AD, Howell TA, Jett M, and Dusek DA (2004) Weighing lysimeters for the determination of crop water requirements and crop coefficients. Appl Eng Agric, 22:851–856

Waziri, U (2007). A review of field lysimeter studies to describe the environmental fate of pesticides. Weed Technol. 10(1):202–209.

William, L.E., and Ayars, J.E (2005). Grapevina water use and crop coefficient are linear function of the shaded area measured beneath the canopy. Agricfo meteorol, 132:201-211.

William, L.E., Ayars, J.E 2005. Grapevina water use and crop coefficient are linear function of the shaded area measured beneath the canopy. Agric fo meteorol, 132 :201-211. calibrated versus the FAO recommended. Agric. Water Manag. 96 (7), 1137–1145.

Yaji M Soil Science for engineer laboratory techniques (2014) Published by lambert academic 96:6-14

Yang, J., Li, B., and Liu, S., (2000). A large weighing lysimeter for evapotranspiration and soil water groundwater exchange studies. Hydrological Processes 14, 1887-1897.

Young, P., Lorite, I.J., Tornero, S., Berengena, J. (1997). Regional calibration of Hargreaves equation for estimating reference ET in a semi –arid, Pp. 223-238.

Zhang, X. Y., Chen, S. Y., Pei, D., Liu, M. Y., & Sun, H. Y. (2005). Evapotranspiration, yield and crop coefficient of irrigated maize under straw mulch. PEDOSPHERE, 15(5), 576-584