



**SURVEY OF THE SOIL PHYSICAL CHARACTERISTICS OF  
ABUBAKAR TAFAWA BALEWA UNIVERSITY FARM AS IT'S RELATE TO  
MOISTURE AVAILABILITY FOR AGRICULTURAL PRODUCTIVITY**

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**ABSTRACT**

A detailed survey of the university farm was conducted, using rigid-grid sampling method to obtain one hundred and forty-four (144) soil samples from 4.7 hectares of land. Surface soil samples of 0-15 and 15-30 cm were collected at grid intersection points. The collected soil samples were air-dried and passed through a 2mm sieve, and analyzed using standard laboratory procedures for physical parameters. Undisturbed soil samples were collected in situ using stainless steel core rings for determination of soil moisture release using pressure membrane apparatus, while double ring infiltrometer was used to determine infiltration rates. Simple linear correlation and regression analysis were conducted to establish relationship between the various data obtained. The findings of the research reveal that out of the analyzed samples, 34 samples were identified as clay, 28, 1, 3 and 6 as sandy loam, sand, silty clay and gravelly sand respectively. At 0.33, 0.5 and 1 bar sandy loam was negatively correlated with clay, while at 5, 10 and 15 bars clay was negatively correlated with sandy loam respectively. The simple linear correlation between bulk density and total porosity indicated a negative correlation at both levels. In conclusion, the linear curve fitting for both Horton and modified Kostrakov's infiltration equations yielded a positive coefficient of determination(R) of 0.992 and 0.982 respectively. Therefore, it is recommended that sandy loam with preponderance of small, medium and large soil particles is capable of retaining soil moisture at different tension levels and should be preferably used for farming activities in the University farm.

**Keywords:** Survey, Soil, Moisture, Properties, Infiltrometer, Models

**INTRODUCTION**

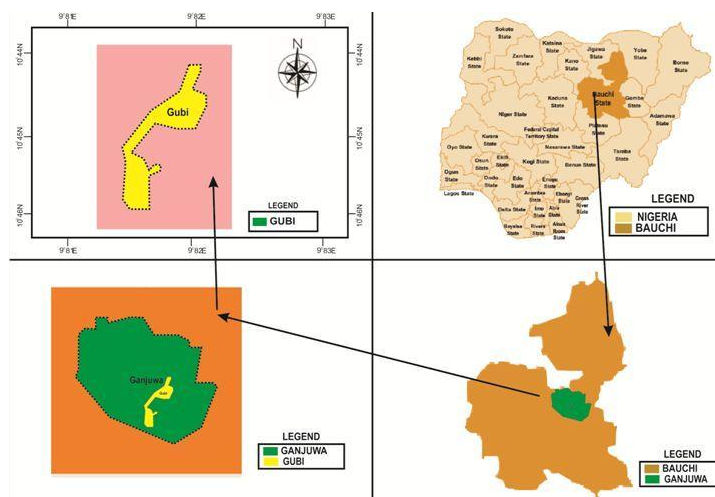
Soil physical properties are the basic and fundamental unit of soil. They serve as the foundation and essential components that characterize the nature and behavior of soil. These properties of soil are important in agricultural contexts because they affect water retention, availability of nutrients, aeration, and the growth of roots (Andreas *et al.*, 2020). A comprehensive understanding of these properties facilitates the implementation of improved management strategies aimed at promoting soil health and enhancing agricultural yields. Furthermore, the physical characteristics of soil significantly contribute to the enhancement of its chemical and biological properties (Ehiem *et al.*, 2016). It is a misconception and a myth that agricultural productivity can be sustained by addition of fertilizer and/or water per se. Expensive inputs can be easily wasted if soil physical properties are suboptimal or below the critical level. Under adverse soil physical conditions, applied Fertilizer, amendments, and pesticides can be leached out, washed away, volatilized, miss the target, and pollute the environment (Abubakar 2015). Therefore, high soil physical quality plays an important role in enhancing soil chemical and biological qualities. As modern agriculture is shifting toward sustainable practices, soil physical properties are more important now than ever before in sustaining agricultural productivity due to the shrinking global per capital of arable land area. It was 0.50 ha in 1950, 0.20 ha in 2000, and may be only 0.14 ha in 2050 and 0.10 ha in 2100. Therefore, preserving and restoring world soil resources is crucial to meeting demands of the present population without jeopardizing needs of future generations. Soil moisture significantly influences weather and climate, plant growth and productivity, hydrology, and soil ecology (i.e., carbon/nitrogen dynamics, and trace gas emissions). As such, the need for compilation of extensive and intensive soil moisture information has been recognized for several decades. Research efforts to develop new techniques for

monitoring soil moisture also continue, often with focus on large-scale monitoring. One prominent area of research is remote sensing. Remote sensing techniques offer promise; however, may provide information only for the top few centimeters of the soil (Ehiem *et al.*, 2016). Therefore, application of remotely sensed soil moisture data may be limited for determining conditions at typical plant rooting depths or for other ecological and hydrological applications, without significant complementary information from proximal (field) measurement (Ehiem *et al.*, 2016). Proximal sensing tools are in direct contact or very close with the soils, therefore the proximity is high compared to remote sensing. The study was therefore carried out to conduct a survey on the soil physical properties of university farm and assess the influence of these properties on moisture retention and release.

## METHODOLOGY

### Description of the Study Area

The study area is the Departmental Research Farm for Crop Production of the Abubakar Tafawa Balewa University (A.T.B.U), which is located at the permanent site of Abubakar Tafawa Balewa University, Gubi Campus, Ganjuwa, Bauchi State, Nigeria. The area is located 25 kilometers away from Bauchi metropolis. It has a total land area of 48km<sup>2</sup> and lies within Savanna zone at Latitude 10°45'N and longitude 9°82'E with an annual average rain fall of 250 mm occurring mainly during the month of June to September.



**Figure 1:** Map of the Study Area.

### Methods of Data Collection

A detailed survey typed was used at a scale of 1:12000. This is according to Brady and Weil that area of land ranging from 0.5 – 5.2 hectares should be categorized under detailed survey for agricultural purpose. The survey method used is rigid grid. This is because the method is useful for large scale highly intensive detailed and detailed survey. The sample point along the traverses can be located and mapped with accuracy.



**Figure 2:** Rigid Grid Survey of the Area using ArcGIS 10.0

### Sampling Techniques

Samples were collected (from grid intersection points) at 72 collection points for 0-15cm as well as 72 collection point for 15-30cm respectively, given a grossed total of 144 samples.

### Particle Size Determination

The first stage involved composite sampling where 6 samples from each data collection point were transformed into 1 sample. The soils were air dried, gently crushed with a wooden roller to break up the clods/peds. After that, the soils were sieved with a 2 mm sieve for analysis. The samples were stored in properly labeled soil bags (polythene bag) from which portions were taken for all physical properties analysis. Particle size distribution (to ascertain texture) was carried out using Bouyoucos hydrometer method as outlined by Gee and Or (2002).

### Soil Preparation for Hydrologic Conductivity

Undisturbed soil samples were prepared and confined within stainless steel rings according to the procedures described by Fong *et al.* (2018).

### Field Test for Infiltrometer

Infiltration rate was determined in the study area using double ring infiltrometer as outlined by Wells and Moure (1986).

### Statistical Analysis

#### Modified Kostiakov Model

$$I = i_c t + \alpha t^\beta \quad \dots\dots\dots(1)$$

Where,  $\alpha(\alpha > 0)$  and  $\beta$  ( $0 < \beta < 1$ ) are constants,  $i_c$  = final infiltration rate (cm/hr),  $i$  = infiltration rate (cm/hr),  $t$  = time and  $I$  = infiltration rate.

#### Horton Model

$$i = i_c + (i_0 - i_c) e^{-kt} \quad \dots\dots\dots(2)$$

Where,  $i$  = infiltration rate at time,  $t$ , (cm/hr),  $i_0$  = initial infiltration rate (cm/hr) at  $t = 0$ ,  $i_c$  = final infiltration rate (cm/hr),  $k$  = infiltration decay coefficient in dimension of time,  $t$ , ( $t^{-1}$ ).

#### Simple Linear Correlation Formula

$$r = \frac{\sum xy}{\sqrt{(\sum x^2)(\sum y^2)}}$$

#### Simple Linear regression formula

$$y = \alpha + Bx$$

$B$  = slope

$\alpha$  =  $y$  - intercept

$y$  =  $y$  - coordinate

$x$  =  $x$  - coordinate

#### Coefficient of uniformity

$$C_u = \frac{D_{60}}{D_{10}}$$



**Coefficient of curvature**

$$Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

**T-test Formula**

$$t = \frac{x_1 - x_2}{\sqrt{s_1^2 + s_2^2} \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

where  $x_1$  = mean value Horton's Model  
 $x_2$  = mean value of Kostiakov's Model  
 $s_1$  = standard deviation of Horton's Model  
 $s_2$  = standard deviation of Kostiakov's Model  
 $n_1$  = numbers of observation of Horton's Model  
 $n_2$  = numbers of observation of Kostiakov's Model

**RESULTS AND DISCUSSION**

**Particle Size Analysis**

Table 1 presents a grouping of the various soil samples into different textural classes from the detailed analysis of particle size distribution of the soil sample obtained from the University farm. The distribution comprises various proportions of gravel, sand, silt, and clay, which were critical for categorizing the soil into distinct textural classes (Figure 3). This classification underscores the heterogeneity of the soil within the study area, allowing for an apparent understanding of its composition. Brady *et al.* (2015) assert that soil texture was a fundamental and enduring property of any soil type, as it remains relatively stable over time and does not easily undergo alterations. This intrinsic characteristic of soil texture was pivotal for making informed management decisions regarding the agricultural practices employed in the University farm. Furthermore, Skaggs *et al.* (2011) underscored the significance of soil texture as a primary physical property, thereby advocating for its critical role in formulating effective water management strategies. The understanding of soil texture lays the groundwork for optimizing irrigation practices, enhancing crop yields, and ensuring sustainable land use, thus reinforcing the necessity for detailed soil classification in agricultural research and practice.

**Table 1:** Textural Classes of Soils of the Study Area

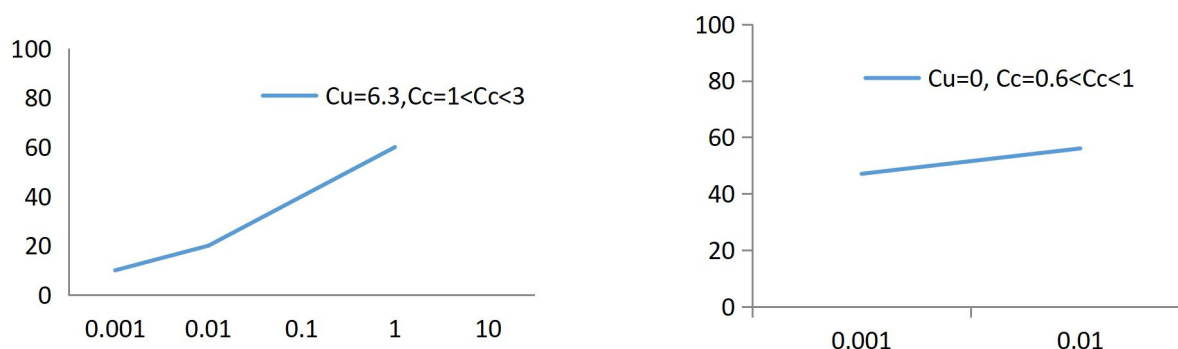
Group	Transverse and intersection (point of data collection)									No. of point of collection involved	Textural classes
Site A	T <sub>1</sub> P <sub>5</sub>	T <sub>1</sub> P <sub>6</sub>	T <sub>1</sub> P <sub>7</sub>	T <sub>1</sub> P <sub>8</sub>	T <sub>1</sub> P <sub>9</sub>	T <sub>2</sub> P <sub>6</sub>	T <sub>2</sub> P <sub>7</sub>	T <sub>2</sub> P <sub>8</sub>	T <sub>2</sub> P <sub>9</sub>	28	Sandy loam
	T <sub>3</sub> P <sub>7</sub>	T <sub>3</sub> P <sub>8</sub>	T <sub>3</sub> P <sub>9</sub>	T <sub>4</sub> P <sub>6</sub>	T <sub>4</sub> P <sub>7</sub>	T <sub>4</sub> P <sub>8</sub>	T <sub>4</sub> P <sub>9</sub>	T <sub>5</sub> P <sub>6</sub>	T <sub>5</sub> P <sub>7</sub>		
	T <sub>5</sub> P <sub>8</sub>	T <sub>6</sub> P <sub>6</sub>	T <sub>6</sub> P <sub>7</sub>	T <sub>7</sub> P <sub>5</sub>	T <sub>7</sub> P <sub>6</sub>	T <sub>8</sub> P <sub>5</sub>	T <sub>8</sub> P <sub>6</sub>	T <sub>4</sub> P <sub>8</sub>	T <sub>3</sub> P <sub>4</sub>		
	T <sub>5</sub> P <sub>9</sub>										
Site B	T <sub>1</sub> P <sub>1</sub>	T <sub>1</sub> P <sub>2</sub>	T <sub>1</sub> P <sub>3</sub>	T <sub>1</sub> P <sub>4</sub>	T <sub>2</sub> P <sub>1</sub>	T <sub>2</sub> P <sub>2</sub>	T <sub>2</sub> P <sub>3</sub>	T <sub>2</sub> P <sub>4</sub>	T <sub>2</sub> P <sub>5</sub>	34	Clay
	T <sub>3</sub> P <sub>2</sub>	T <sub>3</sub> P <sub>3</sub>	T <sub>3</sub> P <sub>4</sub>	T <sub>4</sub> P <sub>3</sub>	T <sub>5</sub> P <sub>1</sub>	T <sub>5</sub> P <sub>2</sub>	T <sub>5</sub> P <sub>3</sub>	T <sub>5</sub> P <sub>4</sub>	T <sub>6</sub> P <sub>2</sub>		
	T <sub>6</sub> P <sub>3</sub>	T <sub>7</sub> P <sub>1</sub>	T <sub>7</sub> P <sub>2</sub>	T <sub>7</sub> P <sub>3</sub>	T <sub>8</sub> P <sub>1</sub>	T <sub>8</sub> P <sub>2</sub>	T <sub>8</sub> P <sub>3</sub>	T <sub>8</sub> P <sub>4</sub>	T <sub>9</sub> P <sub>1</sub>		
	T <sub>9</sub> P <sub>2</sub>	T <sub>9</sub> P <sub>3</sub>	T <sub>9</sub> P <sub>4</sub>	T <sub>10</sub> P <sub>1</sub>	T <sub>10</sub> P <sub>2</sub>	T <sub>10</sub> P <sub>3</sub>	T <sub>11</sub> P <sub>1</sub>				
Others	T <sub>3</sub> P <sub>5</sub>	T <sub>3</sub> P <sub>6</sub>	T <sub>4</sub> P <sub>4</sub>	T <sub>4</sub> P <sub>5</sub>	T <sub>5</sub> P <sub>5</sub>	T <sub>6</sub> P <sub>5</sub>				6	Gravelly sand
	T <sub>4</sub> P <sub>2</sub>	T <sub>6</sub> P <sub>4</sub>	T <sub>11</sub> P <sub>2</sub>							3	Silty clay
	T <sub>6</sub> P <sub>6</sub>									1	Sand
<b>Total</b>										72	





**Figure 3:** Textural Classes of Soils in the University Farm

The gradation curve depicted in Figure 4 provides a comprehensive analysis of the particle size distribution for sandy loam at Site A, indicating its classification as a well-graded soil. The coefficient of uniformity ( $C_u$ ) for this particular sample is determined to be approximately 6.13, while the coefficient of curvature ( $C_c$ ) falls within the range of  $1 < C_c < 3$ . Supporting this assertion, Skaggs *et al.* (2011) highlighted that well-graded soils provide plants with an optimal moisture supply when compared to poorly graded soils, as illustrated in Figure 3. In contrast, Site B presents a distinctly different scenario; it was classified as poorly graded, with a predominance of clay particles. Such soils typically exhibit limited drainage capacity and can pose significant challenges for agricultural practices due to their tendency to retain excess moisture and become compacted (Figure 3).



**Figure 4:** Gradation Curve for Clay and Sandy Loam Soil of the University Farm

### **Infiltration Rates and Infiltration Models**

Table 2 and 3 provides a comprehensive information of both the measured and calculated infiltration rates across the eleven transverses evaluated in the study. The process of linear curve fitting was employed to derive the rate constants for both Horton's infiltration equation and the modified Kostiakov's infiltration model. The statistical analysis yielded notably high coefficients of determination ( $R^2$ ) of 0.992 and 0.982, respectively, indicating a very strong correlation between the observed data and the predictions made by these models. This level of fit suggested that both models reliably represent the infiltration dynamics of the soils under study. Furthermore, the research conducted by Abubakar, 2015 and Abdulkadir *et al.*, (2013) has demonstrated impressive performance of the Horton model, utilizing both linear and nonlinear least squares regression techniques to derive accurate infiltration predictions.

**Table 2: Relationship between Measured and Calculated Infiltration Ratios**

Measurement point	Regression equation <sup>a</sup>	R <sup>2</sup> <sub>MK<sup>a</sup></sub>	R <sup>2</sup> <sub>H<sup>b</sup></sub>
1	y = 2.0414x	0.970	0.981
2	y = 1.1761x	0.930	0.926
3	y = 1.3976x	0.890	0.993
4	y = 1.5441x	0.960	0.968
5	y = 2.0631x	0.970	0.934
6	y = 1.8751x	0.860	0.960
7	y = 1.954x	0.940	0.991
8	y = 1.7628x	0.960	0.992
9	y = 0.9542x	0.985	0.997
10	y = 2.1131x	0.935	0.991
11	y = 2.1139x	0.937	0.993
<b>Mean</b>		<b>0.982</b>	<b>0.992</b>

MK<sup>a</sup> = Modified Kostiatov's Model Simple Linear Regression Coefficient  $p < 0.005\%$

H<sup>b</sup> = Horton Model Simple Linear Regression Coefficient  $p < 0.005\%$

**Table 3: Estimates of the Decay Time (min<sup>-1</sup>) obtained for the Eleven Measurement Point**

Measurement	K <sup>a</sup>	R <sup>2</sup>
1	0.063	0.970
2	0.052	0.930
3	0.048	0.890
4	0.061	0.960
5	0.063	0.970
6	0.047	0.860
7	0.056	0.940
8	0.057	0.960
9	0.038	0.810
10	0.066	0.985
11	0.054	0.935

<sup>a</sup> Decay time constant from the experimental regression plot of  $(f - f_c)/(f_0 - f_c)$  versus time

The two-tailed T-test values between R<sup>2</sup> values for both Horton and modified Kostiatov's were statistically not significant at  $P < 0.005\%$ , hence modified Kostiatov's can be alternatively used as substitute for Horton Model in estimate of infiltration rate in the University Farm (Table 4).

**Table 4: Two-Tailed T-test Result between Modified Kostiatov's and Horton Models**

Sources of Variation (SV)	Models	
	Modified Kostiatov's	Horton Model
Mean	0.982	0.992
Std. Deviation	464	462
Std. Error mean	167.3	166.4
$P < 0.005\%$ <sup>a</sup>	NS	NS

<sup>a</sup> T-test value at  $p < 0.005\%$ .

### Moisture Retention and Release

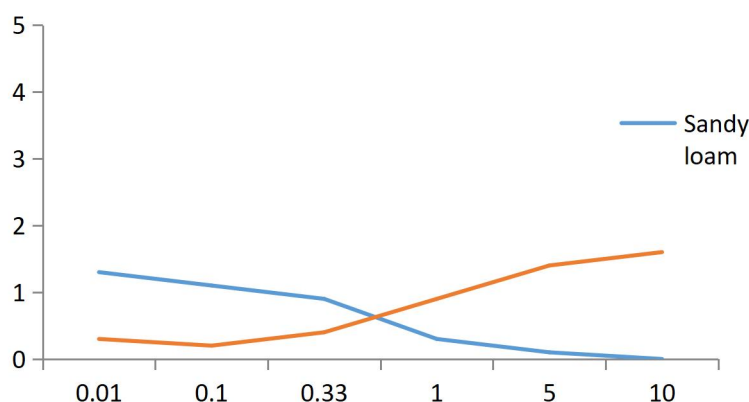
Table 5 shows simple linear correlation analysis between the bulk density and total porosity. The result indicated at both 0-15 and 15-30 cm, porosity was negatively correlated with bulk density. The implication is that, increase in bulk density will drastically reduce total porosity. Decrease in total porosity with increase in bulk density was similar to the trend reported by Abubakar (2015) in DNP field in samaru. This trend was attributed to increase in bulk density and clay content with increase in depth. Abdulkadir and Habu (2013) reported that organic matter increases the availability of pores space. Therefore, decrease in organic matter down the profile was reported to affect total porosity. Abubakar (2015) also observed that increase in clay content in subsoil will swell and clog conducting pores thereby decreasing the total pore space in the soil.

**Table 5:** Relationship between Bulk Density and Porosity of Site A and B at 0-15 and 15-30cm respectively.

Simple linear correlation	Soil Depth (cm)	Site A Bulk density	Site A Porosity	Site B Bulk density	Site B Porosity
Bulk density	0 – 15	1	- 0.96	1	- 0.98
	15 – 30	1	- 0.89	1	- 0.98
Porosity	0 – 15	- 0.92	1	- 0.80	1
	15 – 30	- 0.90	1	- 0.87	1
P < 0.005% <sup>a</sup>		*	*	*	*

<sup>a</sup> Simple linear correlation  $p < 0.005\%$

As illustrated in Figure 5, at tensions of 0.33, 0.5, and 1 bar, sandy loam exhibits a negative correlation with clay soil. This suggests that sandy loam retains less water under these tensions at both 0-15 and 15-30cm, making it more readily available for plant uptake compared to the clay soil of the University farm. Furthermore, at tensions of 5, 10 and 15 bars, clay soil shows a negative correlation with sandy loam. This indicates that, at higher tensions, clay soil retains a greater amount of water than sandy loam. Weil *et al.*, (2015) and Fernando *et al.*, (2002) have defined plant-available water as that held at matric potentials ranging from -10 kPa (-0.1 bar) to -300kPa (-3 bar).



**Figure 5:** Moisture Retention Curve for Sandy Loam (Site A) and Clay Soil (Site B) of the University Farm.

## CONCLUSION AND RECOMMENDATION

In conclusion, the linear curve fitting for both Horton and modified Kostrakov's infiltration equations yielded a positive coefficient of determination ( $R^2$ ) of 0.992 and 0.982 respectively. The simple linear correlation between bulk density and total porosity at both 0-15 and 15-30cm indicated a negative correlation between total porosity and bulk density respectively. The results of the research ought to be integrated into plant response-based models as an element of precision agriculture. Therefore, it is recommended that sandy loam with preponderance of small, medium and large soil particles was capable of retaining soil moisture at different tension levels should be preferably used for farming activities in the University farm.

## REFERENCES

- Abdulkadir A., Wuddivira, M.N., Abdul, N. and Mudiare, O. J. (2011). Use of Horton Infiltration Model in Estimating Infiltration Characteristics of an Alfisol in the Northern Guinea Savanna of Nigeria. *Journal of Agricultural Science and Technology*. **1**(2):163-184.
- Abdulkadir, A. and Habu, S.T. (2013). Soil Properties of a Fallow Field under Long-term Cultivation and Fertilization Regimes in Northern Guinea Savannah. Nigeria. *African Journal of Agricultural Research*. **8**(42):5211-5220.



- Abubakar, G.H. (2015). *Hydraulic Characteristics and Temporal Variability of Soil Properties under a Long-Term Trial in Samaru, Northern Guinea Savanna of Nigeria*. A Thesis Submitted to the School of Postgraduate Studies, Ahmadu Bello University, Zaria in Partial Fulfillment of the Requirements for the Award of a Master's degree in Soil Science. Page 45.
- Andreas, F., Karen, S., Franz, P., Fernando, O. and Pablo, O. (2020) Water Balance and Soil Moisture Deficit of Different Vegetation Units under Semiarid Conditions in the Andes of Southern Ecuador. *Journal of Multidisciplinary Digital Publishing Institute (MDPI)*. **8**(2):120-140. Doi10.3390/cli8020030.
- Brady N. C. and Weil R.R. (2015). *The Nature and Properties of Soils*. Fifteen Edition; Global Edition. Pearson Publication England.
- Ehiem J. C., Ndirika V. I., and Unkwuka U. N., (2016). Effect of Moisture Content on Some Physical Properties of *Canarium schweinfurthii* Engl. Fruits. *Journal of Research for Agricultural Engineering*. **62**:162-169.
- Esen E.S., Hein L. and Cuceloglu G. (2023). Accounting for the Water Related Ecosystem Services of Forests in the Southern Aegean Region of Turkey. *Online Journal of Science*. <https://doi.org/10.1016/j.ecolind.2023.110553>.
- Fong, N. and Ejikelkamp R. (2018). Operational Procedure Membrane Apparatus. User Manual by Royal Ejikelkamp.
- Gee, G.W. and Or, D. (2002). Particle Size Analysis. In: Dane, J.H. and Topp, G.C., Eds., *Methods of Soil Analysis, Part 4, Physical Methods*, Soil Science Society of America, Book Series No. 5, Madison, 255-293.
- Skaggs, T.H. (2011). Assessment of Critical Path Analysis of the Relationship between Permeability and Electrical Conductivity of Pore Networks. *Advances in Water Resources*. **34**(10): 1335-1342.
- Wells L.G., Ward A.D., Moure I.D. and Phillips R.E. (1986). Comparison of Four Infiltration Models in Characterizing Infiltration Models through Surface Mine Profile. *Journal of Biosystems and Agricultural Engineering*. **1**: 184-197. [https://uknowledge.uky.edu/bae\\_fcpub/184](https://uknowledge.uky.edu/bae_fcpub/184).
- Lal, R. (2010). Enhancing Eco-Efficiency in Agro-ecosystems through Soil Carbon Sequestration. *Crop Science*, **50**: 120–131.
- Udong, J. (2007). Evaluation of Empirical Formulae for Determination of Hydraulic Conductivity Based on Grain-size Analysis. *Journal of American Science*, **3**(3): 54-60.