Global Journal of Researches in Engineering: E
Civil And Structural Engineering
Volume 18 Issue 2 Version 1.0 Year 2018
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Predicting Dry Density of Soil from Some Physical and Chemical Properties

By Dhurgham Abdul-Jaleel Rasool Al-Hamdani, Hana Mahmoud Amer Al-Kasaar & Hussain Ali Muhammad Zani
Al-Furat Al-Awsat Technical University

Abstract- The prediction of dry density play important role in projects or major or laboratory tests which required to estimates the value of dry density for cohesion less soils to decision of the solution of these soils or conducting tests. In this paper, an attempt utilized to predict the value cohesion less soil form known some physical and chemical properties of soil such as (LL,PL,PI,**ω**,Gs,F200,TSS,SO_3 and OM). The data utilized in this study is toked from Al-Najaf technical institute Laboratory which conducted for ninety nine cohesion less soil samples. These tests may classify aseasier, cheaper and low time consume when compared with laboratory dry density tests. The results show many correlation models depending on the independent variables constricted to estimate the dry density of soil. The highest coefficient of determination resulted from this study is 0.92 for multiple regression analysis. In this case nine soil property correlated to gathers to estimate the dry density. This value may decrease when the independent variable are decrease than nine soil property.

Keywords: *regression, liquid limit, plastic limit, correlation, water content, density.*

GJRE-E Classification: *FOR Code: 290899*

PREDICTINGDRYDENSITYOFSOILFROMSOMEPHYSICALANDCHEMICALPROPERTIES

Predicting Dry Density of Soil from Some Physical and Chemical Properties

Dhurgham Abdul-Jaleel Rasool Al-Hamdani [α], Hana Mahmoud Amer Al-Kasaar [σ] & Hussain Ali Muhammad Zani [ρ]

Abstract- The prediction of dry density play important role in projects or major or laboratory tests which required to estimates the value of dry density for cohesion less soils to decision of the solution of these soils or conducting tests. In this paper, an attempt utilized to predict the value cohesion less soil form known some physical and chemical properties of soil such as (LL,PL,PI,ω,Gs,F200,TSS,SO_3 and OM). The data utilized in this study is toked from Al-Najaf technical institute Laboratory which conducted for ninety nine cohesion less soil samples. These tests may classify aseasier, cheaper and low time consume when compared with laboratory dry density tests. The results show many correlation models depending on the independent variables constricted to estimate the dry density of soil. The highest coefficient of determination resulted from this study is 0.92 for multiple regression analysis. In this case nine soil property correlated to gathers to estimate the dry density. This value may decrease when the independent variable are decrease than nine soil property.

Keywords: regression, liquid limit, plastic limit, correlation, water content, density.

I. Introduction

Soil density, characterized as the evident density of field soil and ascertained from the stove dry mass per unit volume of field soil, is an imperative soil property that outlines general soil auxiliary attributes. It is a crucial information necessity for all intents and purposes every numerical model portraying the exchange and connection of soil substance constituents inside the ecosphere. Mass thickness is a generally straight-forward property to gauge and a number of broad datasets have been accumulated (Hall et al., 1977; Rawls et al., 1981). Along these lines, few endeavors have been made to create approachesp;o0 for its forecast from other essential soil properties. Be that as it may, the expanding enthusiasm for creating far reaching national datasets of soil physical properties for use in spatially-or stochastically-based ecological demonstrating (King et al., 1995; Bruand et al., 1996) has unavoidably featured discontinuities in the current estimated datasets. This thusly, has now centered consideration around the need to create algorithmic techniques that can anticipate variety in mass thickness as indicated by the consistent variety of soil properties, for example, molecule size and natural issue content. A few researchers focusing to estimate soil density depending on its physical and chemical properties empirically. Simple and Multiple linear regression were utilized for correlation the physical and chemical properties with soil density. Some of this relationship is shown in Table (1). In this table, the researchers developed limited number of empirical formulae while other researchers focusing on presenting the general behavior of the relation between density with chemical and physical properties. Most of correlation that publish pure empirical formulae which is created byutili zings Data Analysis Tool Bar in Microsoft Excel. As a sample of the relation which explain the general behavior is the relation developed by Tanveera A. et al. (2016); they correlate bulk density with many soil property like (texture, organic matter, and mineral friction as sand, silt, and clay). Twenty five soil samples collected from different a location in Kashmir valley in India. The depth of collected samples ranged between 20 to 35 cm. they conclude that the relation between bulk density and organic matter, porosity, and present of clay minerals are positive with present of sand. The relation of the physical and chemical properties with soil bulk density as mentioned by Traveera et al. are shown in models are shown in (Table 1). This relation created byusing Microsoft Excel. Andres A. (2004), he analyze eight sandy soil samples by conducting maximum dry density, soil classification and measuring the fines content and the uniformity coefficient of these samples. He correlate some of physical properties with the maximum dry density. The correlation were measured and some specific behavioral patterns were encountered and analyzed. He conclude that the correlation between well graded sands and maximum dry density have high coefficient of determination, while the poorly graded sand is lower. Thecorrelation model sproposed by Andres A. was developed using Data Analysis Tool Bar in Microsoft Excel. These correlations are shown in Table (1). Chaudhari, P. R. et al. (2013), They investigate the relations of bulk density of soil with texture, organic matter content have available quantity of macro and micro nutrient. Eight soil samples utilized in this investigation. They conclude that the relationships with all soil properties under investigation are negative relation except the relation with sand content. Besides texture and optimum moisture content, organic matter

Author α σ ρ: Al-Furat Al-Awsat Technical University.
e-mails: inj.drgh@atu.edu.iq, inj.Hana@atu.edu.iq, inj.hus@atu.edu.iq

was also the most effective factor affected on the bulk density of soils. The concluded relation was developed using Data Analysis Tool Bar in Microsoft Excel. These correlations are shown in Table (1).S.H. Hallett, et al. (1998)they utilized the procedure of Rawls (1983) to estimate the bulk density of 1568 soil samples within Wales and England. The present of sand, silt, clay, organic matter and the bulk density were the available data utilize in these procedure. The principle of Rawls procedure is predicting bulk density as dependent variable on other soil properties as independent variables. The relations developed by utilizing Rawls procedure are presented in Table (1).

Table 1: The formula proposed by the other researchers

Researchers	Level of Significance	R^2	Function	Density function of
Tanveera A. et al. (2016)	Significant increase	0.60	-	Sand %
	Significant decrease	0.41	-	Clay %
	Significant decrease	0.75	-	O.M. %
	Significant decrease	0.52	-	n
Andres A. (2004)	Significant increase	0.906	$\gamma_d = 87.715(C_u)^{0.166}$	Clean sand %
	Slightly in poorly graded sand and Significantly in poorly graded sand	-	-	%Fines
	Significantly increase and then slightly increase in low and high plasticity Clay.	-	-	%Fines
Chaudhari, P. R. et al. (2013)	Significant increase	0.909	-	Sand%
	Significant decrease	0.633	-	Clay%
	Significant decrease	0.734	-	Silt%
	Significant decrease	0.886	-	n
	Significant decrease	0.495	-	CaCO3
	Significant decrease	0.661	-	EC
	Slightly decrease	0.2317	-	pH
	Significant decrease	0.887	-	OMC
S.H. Hallett, J.M Hollis and C.A. Keay (1998),	For 8 samples	0.65	$\gamma_b =$ 0.618 + 0.095LogeSilt + 0.100LogeClay + 0.0195LogeSand - 0.178Loge OM	Silt,Clay, Sand, OM
	For 16 samples	0.64	$\gamma_b =$ 5.01 - 0.931LogeSilt + 0.038LogeClay - 0.173LogeSand - 0.365Loge OM	Silt, Clay, Sand, OM

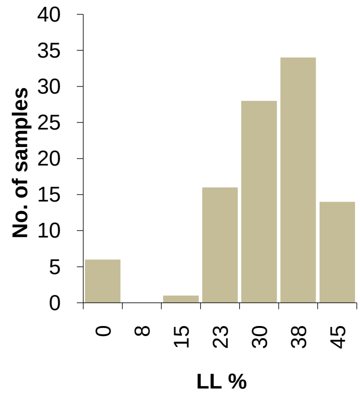
The main purpose of this work is to develop a new correlation system using regression analysis to predict the dry density of soil from physical and chemical properties. The outcomes of this work can be summarized as Develop many simple and multiple correlations model to predict dry density by using regression analyses to decide the best correlation may use to estimate the value of dry density.

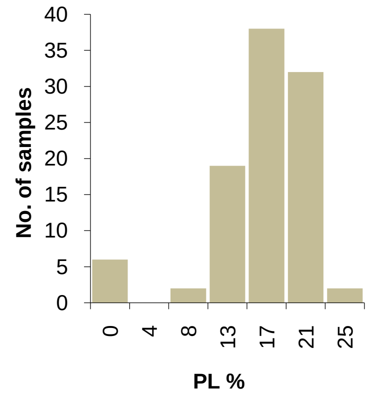
II. Materials and Methods

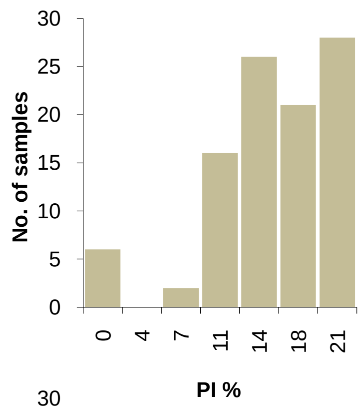
The soil which used in this study is collected from site investigation reports. The soil sample includes different size collected from different locations in Al-Najaf Al-Ashraf City. A ninety-nine of disturbed soil samples were used in this study. The samples were taken from reports of pavement projects and exploration reports during the period from 2005 to 2017. The reports are prepared by scientific and advisory consultant bureauin Al-Najaf Technical Institute. All the tests in reports prepared according to ASTM standards. The selected soil samples include plastic and non-plastic materials. The soil parameters which collected and utilized in the database include organic matter (OM), total suspended solids (TSS), sulfate content (SO_3), natural water content (ω), present fines ($F\#200$), liquid limits (LL), plastic limits (PL), plasticity index (PI), specific gravity (G_S), and dry density (γ_{dry} or γ_d). So as to survey the ampleness of the database, engaging measurements of each dataset exhibits in the database were resolved. Table (2) introduces the elucidating insights of every factor. While the histogram conveyance of the database is appeared in Figure (1). As per the outcomes that show up in Table (2), it can be inferred that the database comprises of an accessible scope of information. In this manner, this database can be utilized for the examination of the execution of existing observational formulae with the correct esteem.

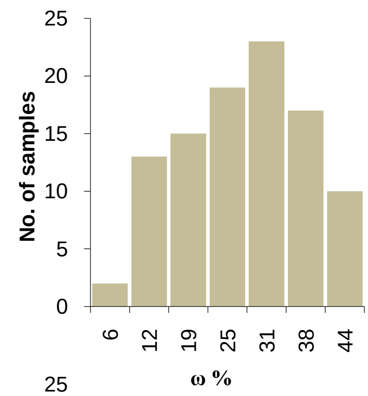
Table 2: Statistical analysis of utilized database

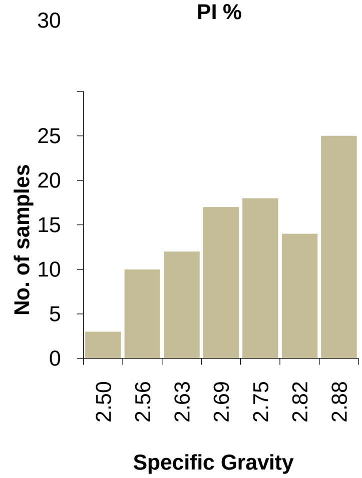
Soil Properties	LL	PL	PI	WC	Gs	F#200	TSS	SO_3	OM	γdry
No. of sample	99	99	99	99	99	99	99	99	99	99
Maximum	45	25	21	44	2.88	57	7	6	8	2.25
Minimum	0	0	0	6	2.5	12	0.02	0.01	0.01	1.5
Range	45	25	21	38	0.38	45	6.98	5.99	7.99	0.75
Mean	27.97	14.11	13.77	24.15	2.71	31.25	2.68	1.86	2.59	1.82
Median	30	15	14	25	2.72	31	2.3	1.5	1.8	1.79
Standard dev.	9.694	4.779	5.077	10.048	0.108	11.994	2.057	1.757	2.494	0.184
Units	%	%	%	%	-	%	%	%	%	gm/cm^3

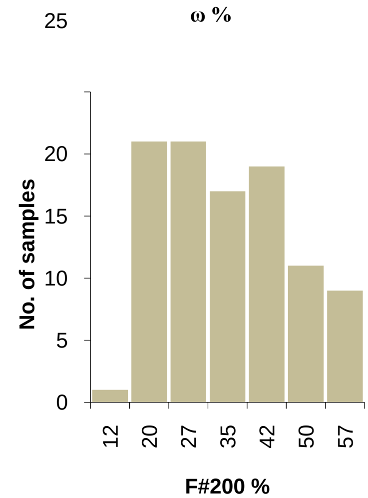












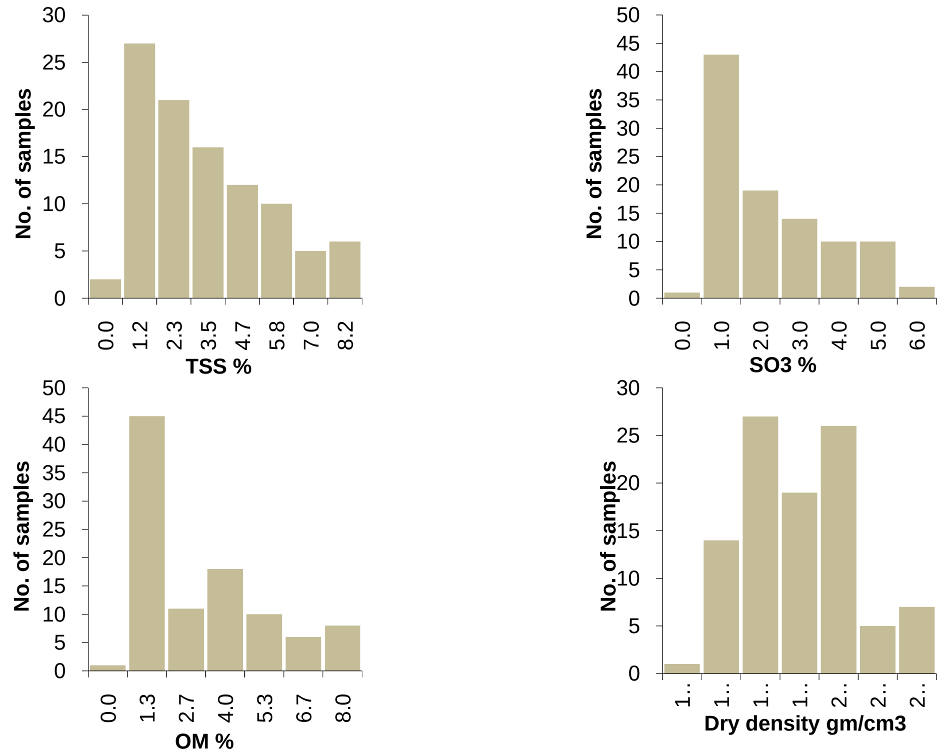


Figure 1: Histogram distribution of database utilized in this study

III. Results and Discussion

Relapse examination is a factual procedure used to assess the connections between factors. It is utilized to comprehend which one of the reliant factors are identified with the free factor and to investigate the types of these connections. Both Single regression analysis (SRA) and multiple regression analysis (MRA) were created in this examination to appraise the value of dry density in view of a portion of the physical and chemical properties by utilizing the chose database.

The trucks choice from Excel was utilized to chart the qualities acquired from the analyses, it was likewise connected an element that is equipped for including a non-straight pattern line to a predetermined arrangement of focuses. The pattern line is a bend characterized from pre-decided capacities, for example, Polynomial, Logarithmic, Power and Exponential. Additionally, the R-squared, known as the coefficient of assurance, can be computed. The R-squared esteem is a pointer that reaches from 0 to 1 and uncovers how intently the assessed esteems from the pattern line compare to the genuine information. The pattern line is more solid when its R-squared esteem is at or close to 1. The chose slant line was unified with the most elevated R-squared esteem. The power work was the nearest guess to the arrangement of focuses got from the tests, this condition has a highest R-squared estimation.

a) Simple Regression Analysis

SRA is the most commonly basic type of regression and utilized in the predictive analysis. There are two things represent the main idea of simple regression analysis: the first is providing the set of predictor variables with good accuracy in predicting an outcome value of the variable, the second, is providing significant predictors variable as a dependent variable. To establish a simple regression between dry density and physical and chemical soil properties, many point are drawn as the (X) coordinate represent the specified soil property and the (Y) coordinate represent the dry density. The best fit line pass through and discussed the variation of most point is the simple regression line, the equation of this line simulate the relation between soil property utilized and dry density. The accuracy of SRA measured by calculating the coefficient of determination (R2). It is a number which explained the reliability of proposed proportion. The coefficient of determination ranged between 0 to 1. The best correlation is the correlation has the coefficient of determination closest to 1. Practically, the value of coefficient of determination equal or greater than 0.8 indicates the acceptable correlation. To develop the models of SLRA on the available database. Data Analysis Tool Bar in Microsoft Excel is utilized. The dry density of soil specified as the dependent variable and other soil properties such as (LL, PL, PI, ω, TSS, OM, and SO_3) specified as independent variable individually. SLRA models for the specified soil property are present in Figure (2) to Figure (10) below.

The correlation formulae and the coefficient of determination are presented in Table (3). As shown in Table (4), model 5 has given the closest coefficient of determination to 1while model 9 given the closest coefficient of determination to 0.

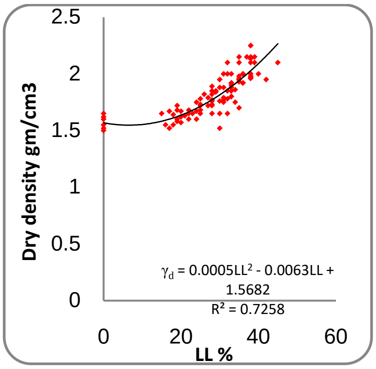


Figure 2: Dry Density vs LL

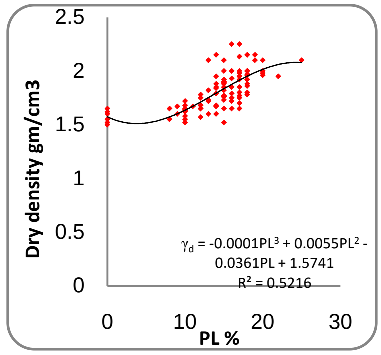


Figure 3: Dry Density vs PL

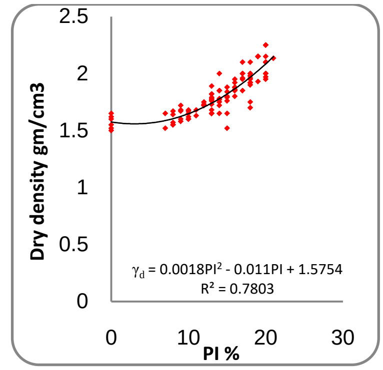


Figure 4: Dry Density vs PI

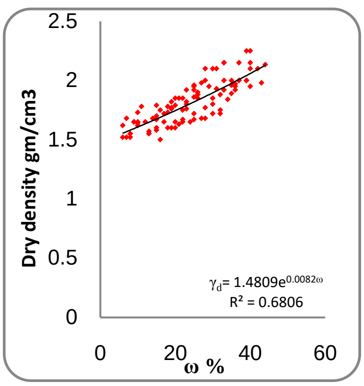


Figure 5: Dry Density vs ω

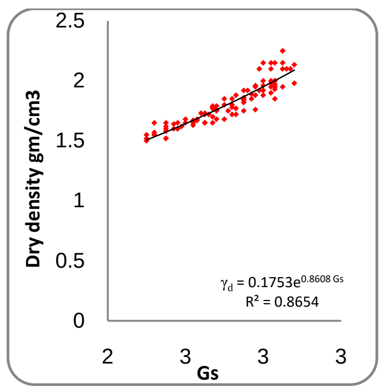


Figure 6: Dry Density vs G_s

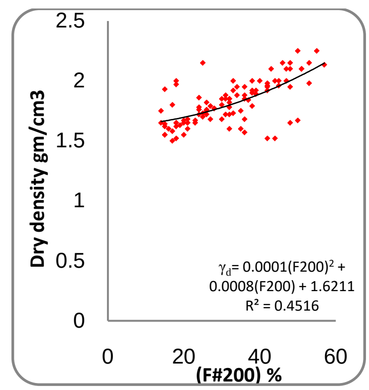


Figure 7: Dry Density vs F# 200

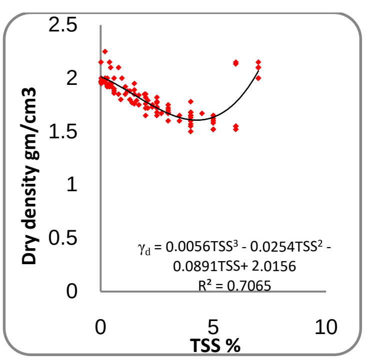


Figure 8: Dry Density vs Tss

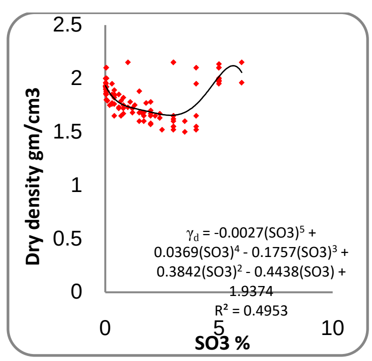


Figure 9: Dry Density vs SO_3

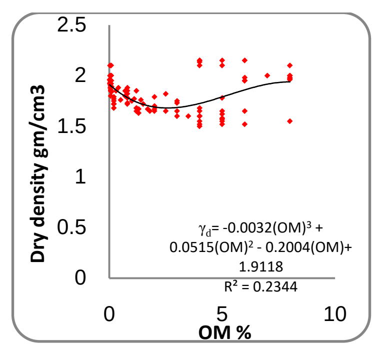


Figure 10: Dry Density vs OM

Table 3: Summary of developed (SRA) to evaluate dry density

SRA	Independent variables	R^2	Developed empirical formulae
Model 1	LL	0.7258	$\gamma d = 0.0005LL^2 - 0.0063LL + 1.5682$
Model 2	PL	0.5216	$\gamma d = -0.0001PL^3 + 0.0055PL^2 - 0.0361PL + 1.5741$
Model 3	PI	0.7803	$\gamma d = 0.0018PI^2 - 0.011PI + 1.5754$
Model 4	Gs	0.8654	$\gamma d = 0.1753e^{0.8608\,Gs}$
Model 5	ω	0.6806	$\gamma d = 1.4809e^{0.0082\omega}$
Model 6	$F200$	0.4516	$\gamma d = 0.0001(F200)^2 + 0.0008(F200) + 1.6211$
Model 7	TSS	0.7065	$\gamma d = 0.0056TSS^3 - 0.0254TSS^2 - 0.0891TSS + 2.0156$
Model 8	$SO3$	0.4953	$\gamma d = -0.0027(SO3)^5 + 0.0369(SO3)^4 - 0.1757(SO3)^3 + 0.3842(SO3)^2 - 0.4438(SO3) + 1.9374$
Model 9	OM	0.2344	$\gamma d = -0.0032(OM)^3 + 0.0515(OM)^2 - 0.2004(OM) + 1.9118$

b) *Multiple Regression Analysis*

To develop the models of multiple regression analysis, dry density value is considered as the dependent variable and physical and chemical soil properties such as (LL, PL, PI, ω, TSS, OM, and SO_3) are considered as independent variables utilized together in developed formula. Six models Table (4) with different soil properties choice from the database to develop the correlation. The statistical parameter as coefficient of determination (R^2) values is calculated. The predicted dry density values are plotted with the actual dry density values provided from database. The best line are drawn to evaluate the variation between the estimated value and the real value. Figure (11) to Figure (14) Explain the variation between real and estimated dry density value.

Table 4: Summary of developed (MRA) to evaluate CBR value

MRA	Independent variables	R^2	Developed empirical formulae
Model 10	LL, PL, PI, ω, Gs, F200, TSS, SO3 and OM	0.92	$\gamma d = -0.32331 + 0.090914\,LL - 0.0947PL - 0.08925PI + 0.000214\,\omega + 0.812355Gs + 0.001807F200 - 0.06588TSS + 0.028297SO3 + 0.008072\,OM$
Model 11	LL, PL, PI, ω, Gs, and F200	0.90	$\gamma d = -1.313028295 + 0.095710046LL - 0.09471365PL - 0.092730055PI + 0.001277011\,\omega + 1.097524369Gs + 0.001872137F200$
Model 12	LL, PL, PI, ω, and Gs	0.89	$\gamma d = -1.408337645 + 0.106414816\,LL - 0.104265638\,PL - 0.104753722\,PI + 0.002239171\,\omega + 1.146455612\,Gs$
Model 13	TSS, SO3, and OM	0.80	$\gamma d = 2.042655154 - 0.109336005\,TSS + 0.037814019\,SO3 - 0.00146424\,OM$
Model 14	LL, PL, and PI	0.73	$\gamma d = 1.445378617 + 0.112257516\,LL - 0.120009326\,PL - 0.078119235\,PI$
Model 15	ω, Gs, and F200	0.84	$\gamma d = -1.886748318 + 0.00075222\,\omega + 1.328356584\,Gs + 0.002640785F200$

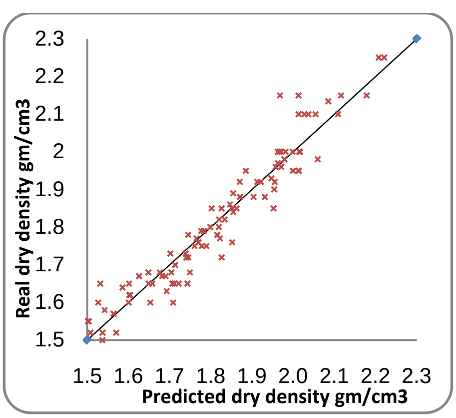


Figure 11: Real VS Predeectied Density for Model 10

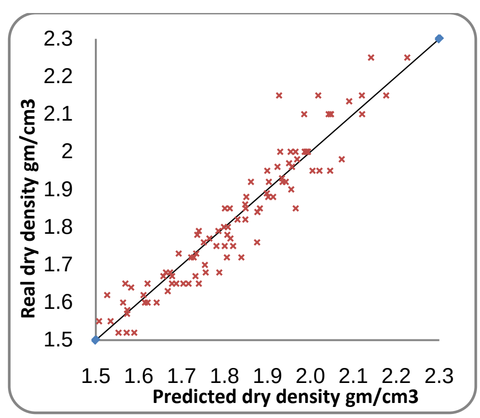


Figure 12: Real VS Predeectied Density for Model 11

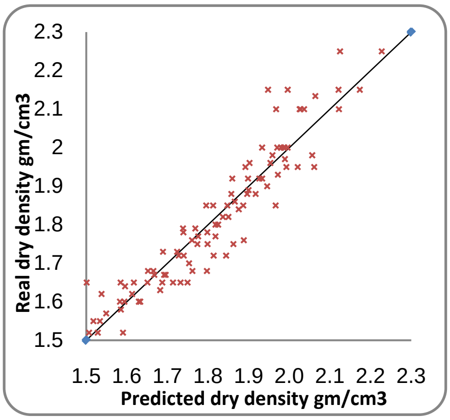


Figure 13: Real VS Predeectied Density for Model 12

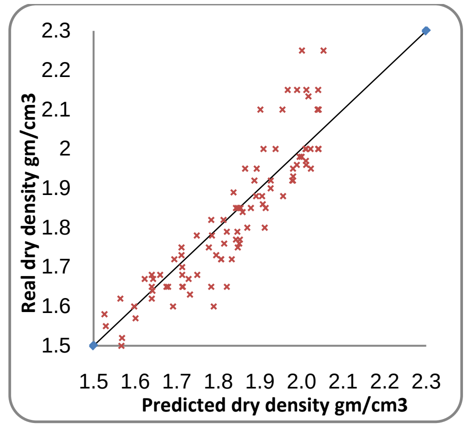


Figure 14: Real VS Predeectied Density for Model 13

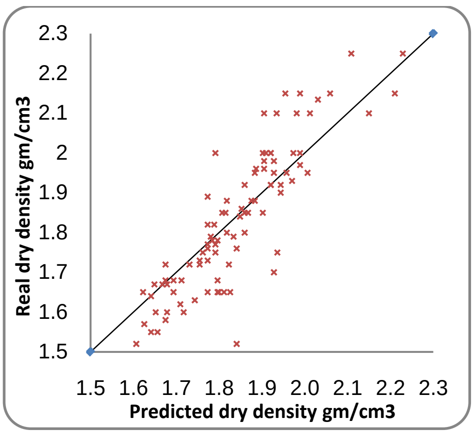


Figure 15: Real VS Predeectied Density for Model 14

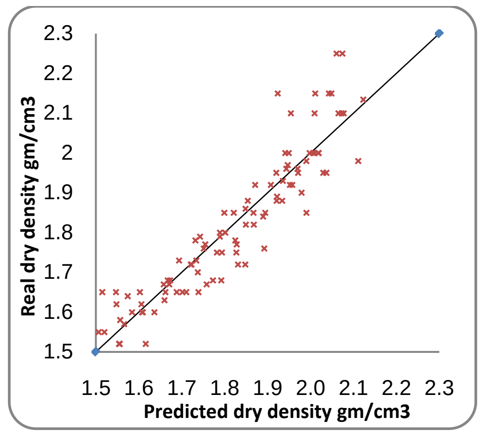


Figure 16: Real VS Predeectied Density for Model 15

IV. Conclusion

Depending on the results of the correlation above, the following points may be concluded:

1. Some soil properties put high coefficient of determination with dry density such as specific gravity and plasticity index while other soil properties put low coefficient of determination such as liquid limit, moisture content, total soluble salts, and plastic limits. This indicating accepted mean, that the soil with higher specific gravity must be higher in dry density.
2. The correlation using more than one soil properties give higher than when using one soil properties.
3. When using effective soil properties in multiple correlation, the coefficient of determination get higher.
4. When increase the samples which are utilized in correlation, the coefficient of determination get higher.

References Références Referencias

1. Hall, D.G.M., Reeve, M.J., Thomasson, A.J. and Wright, V.F., 1977. Water Retention, Porosity and Density of Field Soils, Soil Survey Technical Monograph No. 9. Rothamsted Experimental Station, Harpenden, 75 pp.
2. Rawls, W.J., Brakensiek, D.L. and Saxton, K.F 1981. Soil Water Characteristics. Am. Soc. Agric. Eng. Paper No. 81-2510.
3. King, D., Jones, R.J.A. and Thomasson, A.J. (eds.), 1995. European Land Information Systems for Agro environmental Monitoring. CEC, JRC Ispra, Italy. 284 pp.
4. Bruand, A., Duval, O., Wösten, J.H.M. and Lilly, A., (Eds.). 1996. The use of Pedotransfer in Soil Hydrology Research in Europe. Proceedings of the second workshop. INRA, Orleans, France, 10 12/10/1996. INRA, Orleans and EC/JRC Ispra. 211 pp.
5. Tanveera A., Tasawoor A. Kanth, Parvaiz A. Tali and Mehrajuddin Naikoo (2016), "Relation of Soil bulk Density with Texture, Total organic matter content and Porosity in the Soils of Kandi Area of Kashmir valley," International Research Journal of Earth Sciences, Srinagar, India. ISSN 2321–2527, Available online at: www.isca.in, www.isca.me.

6. Arvelo, Andres, "Effects of the Soil Properties on the Maximum Dry Density Obtained From" (2004). Electronic Theses and Dissertations. http://stars.library.ucf.edu/etd/161.
7. Pravin R. Chaudhari, Dodha V. Ahire, Vidya D. Ahire, Manab Chkravarty and SarojMaity, (2013), "Soil Bulk Density as related to Soil Texture, Organic Matter Content and available total Nutrients of Coimbatore Soil," International Journal of Scientific and Research Publications Vol. 3, No. 1, pp. 2250–3153. doi: 10.2136/sssaj2015.11.0407.
8. Hallett, S.H., Jones, R.J.A. and Keay, C.A., (1998), "Derivation and evaluation of a set of pedogenically based empirical algorithms for predicting bulk density in British soils," National Soil Resources Institute, School of Applied Science, Cranfield University, Cranfield, Bedfordshire, MK43 0PL, Great Britain.