TOPRAK SU İLİŞKİLERİNDE TOPRAĞIN TERMAL ÖZELLİKLERİNİN DEĞERLENDİRİLMESİ

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EVALUATION OF SOIL THERMAL PROPERTIES ACCORDANCE WITH SOIL AND WATER RELATIONSHIPS

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ÖZET

Doktora Tezi

TOPRAK SU İLİŞKİLERİNDE TOPRAĞIN TERMAL ÖZELLİKLERİNİN DEĞERLENDİRİLMESİ

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Toprak termal özellikleri toprak yönetiminde önemli özelliklerdendir. Bu araştırmanın amacı, farklı teksürlü topraklara ait değişik agregat büyüklüklerinde ki örneklerin farklı su içeriklerinde gelişen termal özelliklerini değerlendirmek, tahmin modelleri ile bu özellikleri karşılaştırmak ve yapay toprak düzenleyici olarak polivinil alkolün (PVA) toprağın bazı fiziksel özelliklerini belirlemektir. Araştırmada kaba, orta ve ince bünyeli üç toprak örmeği kullanılmıştır. Denemede 4 mm, 2 mm ve 1 mm elekler kullanılarak, 4-2; 2-1; <4; <2 ve <1 agregat fraksiyonları hazırlanmıştır. Agregat fraksiyonları doygun, tarla kapasitesi ve devamlı solma noktası nem civarlarında silindirik saksılar içerisinde nemlendirilerek örneklerin termal prop yardımıyla sıcaklık değişimleri kaydedilmiş ve bu verilerden yararlanılarak termal iletkenlik değerleri belirlenmiştir. Ayrıca örneklerin hacimsel ısı kapasitesi ve termal diffüzivite değerleri saptanmıştır. Termal iletkenlik ve termal diffüzivite değerleri tahmin modelleri kullanılarak tayin edilmiştir. Toprağın fiziksel özelliklerinden agregat stabilitesi, dispersiyon oranı, hidrolik iletkenlik, kütle yoğunluğu üzerine yapay toprak düzenleyicinin etkileri değerlendirilmiştir.
Araştırma sonuçlarına göre, her üç tekstüre sahip toprak ve agregat büyükleri için toprak nem içeriğinin artışı, termal iletkenlik ve diffüzivite üzerinde artırıcı bir etkiye sahip olmuştur. Denemeye ait veriler ile tahmin modellerinin karşılaştırılması sonucunda, ölçüm değerlerinin, de Vires modeline yakın sonçlar verdiği belirlenmiştir. Agregat fraksiyonları bakımından 4-2 mm civarında ki agregatların diğerlerine göre daha yüksek termal iletkenlik değerleri ortaya koyduğu tespit edilmiştir. Kaba tekstürü topraklar daha yüksek termal iletkenlik, ince tekstürü topraklara göre göstermiştir.

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Anahtar Kelimeler: Toprak su içeriği, termal iletkenlik, termal diffüzivite, termal prob, tahmin modelleri

ABSTRACT

PhD Thesis

EVALUATION OF SOIL THERMAL PROPERTIES ACCORDANCE WITH SOIL AND WATER RELATIONSHIPS

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Soil thermal properties is one of the important properties for the soil management. The aim of this study was the evaluation of the soil thermal properties in the different soil texture, different aggregate sizes under various water conditions, comparison the value of experimental thermal properties measuremnts with the prediction models and the effect of PVA as the soil amendment on the some physical properties of soil. .In this research was used of three texture as fine, medium and coarse. Also, by using of the 4 mm, 2 mm and 1 mm sieves was prepared the aggregate sizes as 4-2 mm, 2-1 mm, <4 mm, <2 mm and <1 mm. The soil samples with different aggregate fractions was filled into the cylinders and recieved to the different moisture conditions as saturation, filed capacity and permanent wilting point and then by using of the thermal needle prob was recorded the temperature changes during the time and then by using of this data was calculate the thermal conductivity values. Also, was calculated the soil samples volumetric heat capacity and thermal diffusivity. Thermal conductivity and thermal diffusivity was determined by using of the prediction models. On the some soil physical properties such as aggregate stability, dispersion ratio, hydraulic conductivity and bulk density was investigated the soil amendments effects. The water content increasing had the raising effects of the thermal conductivity and thermal diffusivity according to the three texture that belonged to the soil and aggregate sizes. Experimental mmeasurement values was close to the de-Vries prediction model in compare to the other models. The 4-2 mm aggregate size showed the most thermal conductivity between the other aggregate sizes. The coarse texture soils were showed high thermal conductivity in compare to the fine texture soils.

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Keywords: Soil water content, thermal conductivity, thermal diffusivity, thermal needle prob, prediction models

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ABBREVIATION and SYMBOL LIST

λ	Thermal conductivity, W/m.K
C_v	Volumetric heat capacity, J /m^3.K
Θ_v	Volumetric water content, m^3.m-^{3}
AS	Aggregate stability, %
K	Hydraulic conductivity, cm/hr
ρ_b	Bulk density, g/cm^3
ρ_P	Particle density, g/cm^3
Q	Heat transfer, J/sec or W
L	Length, m
A	Area of cross section, m^2
ΔT	Difference in temperature, K
E	Voltage, V
I	Current, A
R	Total resistance, Ω
T	Temperature, K
T	Time, sec
S	Slope of curve
α	Thermal diffusivity, m^2/sec
λ_w, λ_a, λ_s	Thermal conductivity of water, air, particles, W/m.K
x_w, x_a, x_s	Volumetric fraction of water, air and soil particles
K_w, K_a, K_s	Weighting factors of water, air and soil particles
g_a, g_c	Shape factors
n	Porosity
λ_f	Fluid thermal conductivity W/m.K
f_w	Empricial weighting function

FIGURES LIST

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1. INTRODUCTION

Soil role for plant growth is undeniable as a result of its role as water and minerals source those storages for plants. Also soil causes to expand root systems for absorption and storage water and nutrition. It is a complex system that consists of different segments such as mineral particles and organic matter that form solid matrix, pore space that was occupied by soil solution and air. In addition, soil usually contains an active segment such as bacteria population, fungi, algae, insects and small animals that directly or indirectly affect on soil characteristics and root growth (Wild 1988).

Soil is a heterogeneous bulk that has three phases' system of solid, liquid and gas. Mineral matter includes sand, silt and clay. Soil organic matter form is the largest fraction of soil that has various proportions. The void space within the solid particles is named the soil pore space (Arriaga and Rubio 2017). Two key factors that have important role for many soil biophysical processes and crop growth are soil temperature and soil water content (Liang *et al.* 2017). Water loss, non-productive water to crop growth is as a result of high temperature and consequently high evaporation (Wang *et al.* 2015). Available soil water that is necessary for plant growth is a potential energy level between field capacity and permanent wilting point condition. Water flow in the soil-plant-atmosphere continuum happens according to the potential energy differences of water in the system. Lower water potential in the plant shoot and root system in compare to bulk soil occur after transpiration; so, soil water moves into the root system according to potential gradient (Kramer and Boyer 1995).

Energy exchange and mass regulation between soil and atmosphere are under two important parameters such as soil temperature and thermal properties (Tyson *et al*. 2001). Soil temperature effects on the soil formation level, through the temperature direct impact on the bedrock weathering for mineral particles producing. Also, the temperature influences on the biological processes, such as the water and nutrients absorption by roots, germination, seedling emergence and plant growth (Bachmann et al. 1997; Hillel 1998; Zawadzki et al. 1999).

The temperature increases the oxygen consumption and the anaerobic sites development in the soil (Maag and Finn 1999), so the soil chemical reactions and the plant growth rate influence by the oxygen ratio (Zawadzki *et al.* 1999). Soil structure has important effect on nutrient, water and gas availability. The daily average soil temperature annual changes at different soil depths can be computed by using of the sinusoidal function (Hillel 1982; Marshall and Holmes 1988; Wu and Nofziger 1999).

Important models inputs can be noted soil thermal properties such as thermal conductivity, specific heat and thermal diffusivity (Evett *et al.* 2012). Soil thermal conductivity has significant impact on the surface energy and causes to the temperature distribution in the soil and moisture flow during the soil length (Usowicz *et al.* 2017). Soil is formed of solid particles and void that can be include water and air. In dry soil the voids between particles only contain air. Heat is conducted by the particles and between particles. If the voids start to fill with water the effective contact area between particles increases as a resulting of increased conduction of heat. There are two mechanisms by which moisture may move away from a heat source in soil. The first is movement in liquid form due to heat weakening surface tension between water and soil particles and the second mechanism is via to vapor movement through the soil (ASTM D2937 2010).

Knowledge about heat capacity and heat flow, soil specific heat capacities can be solve some soil problems. Thermal diffusivity is equal to thermal conductivity divided by volumetric heat capacity and reflects both the soil ability to transfer heat and its ability to change temperature (Arkhangelskaya and Lukyashchenko 2017). About analytical techniques development to predict the thermal conductivity of soils correctly were done some researchers. Soils Thermal-conductivity models are classified as experimental or theoretical. One of the soil temperature properties that attended by researchers for the thermal conductivity models is the effective thermal conductivity that it means the ability of soil to conduct heat (Gangadhara Rao and Sing 1999).

One of the important and required factors for quantitative study of heat and water transfer processes under saturated and unsaturated soils condition is the thermal conductivity and water content relationship. The soils thermal conduction characteristics are strongly influenced by moisture content, density, mineralogy, and other factors Many investigations were performed to quantify the effects of soil moisture, density, mineralogy on soils heat transfer and to predict the soil thermal resistivity. Some theories and empirical prediction models have been offered to estimate the thermal properties of soils. The models performance investigation is done at different soil types and moisture contents. Empirical relationships between the model parameters and soil physical parameters are evaluated to test the efficacy of predicting thermal conductivity. Some theoretical thermal conductivity models have been offered to estimate sand thermal conductivity and most of them are according to resistor equations.

The aim of this study was to evaluation relationships between soil thermal properties and other soil properties such as soil texture, aggregate size and soil water content under different water tensions. The measured data compared with the models predicted data. Also, we investigated polyvinylalcohol (PVA) as synthetic organic polymer effects on some soil properties such as aggregate stability, bulk density, hydraulic conductivity and dispersion ratio.

2. RESOURCE SUMMARIES

Soil thermal properties affect on the energy exchanging into soil-atmosphere system and impacts on plant growth. Soil thermal properties are influenced by soil factors such as water content, bulk density, organic matter content and porosity. Thermal properties of soil such as thermal conductivity, specific heat and thermal diffusivity can be determined by measurements or by using of the soil general properties value.

Evett et al. (2012) evaluated that soil thermal properties have relationship with some factors that can be classified under different groups. These factors such as soil texture, mineralogical composition and organic matter content can effect on the soil thermal conductivity. Minacapilli et al. (2009) resulted that the materiathermal inertia can resistant against to temperature changes. It is as a result of function such as material's bulk density, specific heat capacity and thermal conductivity. Moisture level changes can changes soil thermal conductivity.

Van doninck et al. (2011) studied about the soil thermal conductivity evaluation by remote sensing and showed that bulk density, specific heat capacity and thermal conductivity cannot be insulated from remote sensing, thereby mapping of thermal inertia by remote sensing requires another approach. Some negative effects such as charring, loss of organic matter and atmospheric nitrogen losses can be happened as a result of temperature increasing (Certini 2005; Glass *et al.* 2008; Gray and Dighton 2006; Glass *et al.* 2008; Gray and Dighton 2006) that under this condition, clay minerals break down and aggregate modify the soil as physically (Terefe *et al.* 2008; Kettering *et al.* 2000).

Kang and Sajjapongse (1980) studied about the organic matter and clay ratio relationship and investigated that organic matter decreases strongly as a result of clay minerals physical changes and reduced the soil ability to keep valuable nutrient. Galang et al. (2010) studied on the temperature effects on the soil nutrients and resulted that many macro-nutrients biological availability such as phosphorus, potassium and calcium effected by high temperature by geochemistry changes. Cebron et al. (2009, 2011) and Thion et al. (2012) investigated the soil temperature and microorganism relationship and fixed that soil microbial communities retaining ability can be varied by soil heating, significantly according to the important impacts on nutrient cycling, organic decomposition and bio-polishing of residual contaminants.

Hansen et al. (1990) studied about the important factors for plant growth and soil changes and showed that soil temperature and soil water content are two important factors for soil biophysical processes and crop growth. Stone et al. (1999) studied on soil temperature and its effects on the soil details and resulted that soil temperature can influences on the crop phenology, canopy development, biomass and crop yield. Liang et al. (2017) evaluated soil temperature and plant growth relationship and resulted that high soil temperature can cause to high soil evaporation that is shown as water loss, non-productive water to crop growth.

Hu (2009) and Chang (2011) have investigated the different factors impacts on the soil thermal physical parameters and reported that the specific heat capacity variation influenced on the thermal conductivity. Rising in water content and soil density caused increases in thermal conductivity (Abu-Hamdeh 2001, 2003; Li *et al.* 2009). The effects of ground water seepage on thermal conductivity is more clear (Fan *et al.* 2007; Bozdag and Paksoy 2008; Hu 2009; Lee and Lam 2012).

Dissanayaka et al. (2013) studied about soil thermal properties such as thermal conductivity and the volumetric heat capacity can be controlled soil heat transport. Soil thermal conductivity relegates to the ability of soil to conduct heat. Soil thermal conductivity results was gained by the volumetric properties of the soil components such as organic matter, minerals, water and air content and interfacial contacts between the liquid and solid phase.

Tayson et al. (2001), Dec et al. (2009), Ju et al. (2010) and Dec et al. (2009) noted that soil thermal properties have important role on the surface-energy partitioning and temperature distribution, such as thermal conductivity and volumetric heat capacity that all of these properties are driven by soil moisture distribution and are impacted by soil composition, soil structure and vegetation cover. Soil water content and physical characteristics affecting on soil thermal conductivity also affects on soil tillage.

Kustas et al. (2000) and Ghuman and Lal (1985) studied about the soil covering and soil temperature changes and demonstrated the effects of partial surface vegetation cover mulch and clustering on soil heat flux. Micro-climate can be changed the soil thermal conductivity that in necessary for plant growth. Damufeu et al. (2016) and Meukam et al. (2003) evaluated the pores effects on the soil thermal changes and indicated that the addition of porous aggregates to the bricks improves their thermal insulation performance.

Balland and Arp (2005) and Wu et al. (2015) researched about the effected factors on the soil thermal conductivity and showed that the moisture content, dry density and mineralogy composition have significant influenced on the value of thermal resistivity or conductivity of soils. Simas et al. (2007) Bockheim et al. (2013) and Pereira et al. (2013) studied about soil profile temperature measurements and temperature changes during the profile and explained the depth of the active layer, heat flux during seasonal freezing and thawing regimes.

The energy exchange mechanisms from surface to deep layers of soil profile and water flow with seasonal processes cause freezing and thawing and so directly affects on climate system (IPCC, 2014). Markle et al. (2006) and Abbasy et al. (2014) studied about soil temperature and soil thermal conductivity variation relationship and showed that the actively induced temperature changes will depend on soil thermal conductivity as well as on heat flow affected by soil moisture.

Weiss (2003) researched about soil temperature changes and thermal conductivity variation and showed that there was linear relationship between soil temperature data and thermal conductivity. Sayde et al. (2010) indicated a concept of cumulative temperature increasing that is explained as the integration of temperature changes during the measuring period and estimated the soil moisture content. Johansen (1975), Chen (2008), Farouki (1981) and Zhang et al. (2015) resulted that soil thermal conductivity under moist or saturated condition was higher in compare to the condition under dry or nearly dry. According to this, can be noted the effect of water content on soil thermal conductivity. Against this result, the bulk density impacts are low on soil thermal conductivity.

Zhang et al. (2015) researched about thermal conductivity and physical factors that have effect on the soil thermal conductivity and showed that although bulk density can be increase the physical factors number that influence on the soil thermal conductivity but thermal conductivity is not increased, significantly. Farouki (1986) resulted that soil solids thermal conductivity is higher than water and air thermal conductivity. The soils thermal conductivity are a function of several parameters such as dry density, water content, mineralogy, temperature, particle size, particle shape and the volumetric proportions of the soil constituents. The soils thermal conductivity can be determined both by the laboratory testings and in the field by transient or steady state methods.

The large diameter of the probe can cause to make error as the departure error. Thin probe did not show this error as high as large prob. Also, thin probe can be measure thermal conductivity correctly as needle probe (ASTM 2008). Abu-Hamdeh et al. (2000) studied about the organic matter effects on the soil thermal conductivity and indicated that the soil organic matter percentage increasing caused to reduce thermal conductivity. Thermal conductivity values were higher for sand soil in compare to the clay loam soil.

Chacko and Renuka (2002) studied about the thermal conductivity researches importance and resulted that estimation of thermal conductivity from the soil temperature data can provide an understanding of the gain or loss of heat by the soil from the atmosphere. Abareshti et al. (2010) measured the nanofluid thermal conductivity as a fuction of the particle volume fraction under different temperatures condition. They deduce that the thermal conductivity increasing happened by the both particle volume fraction and temperature increasing.

Temperature increasing causes to raise the thermal conductivity (Campell *et al*. 1994; Smits *et al.* 2013). The non-linear relationships are considered between thermal conductivity and soil-water content $\lambda(\theta)$ (Campbell, 1985; Cote and Konrad 2005). Yoshikawa et al. (2003) resulted that the shallow surface layers thermal conductivities are depended on the composition and state of the soil and vegetation. Water and ice content changes cause to thermal conductivity greatest changes as temporally.

Thomas and Rees (2009) and Choi et al. (2011) were evaluated the effect of soil saturation on the heat exchange rate as numerically and resulted that water content increasing can modified the heat exchange during soil profile. Abu-Hamdeh and Reeder (2000) studied about some soil properties such as variable soil water status, bulk density and less variable organic matter content and resulted that these properties effect on the soil thermal conductivity, significantly.

Ochsner et al. (2001) compared the thermal conductivity relationship with air pore and water content and indicated that the correlation between thermal conductivity and air-filled porosity is more strongly in compare to its correlation with water volume fractions. Carminati et al. (2008), Horn and Smucker (2005), Lipiec et al. (2012) and Slawinski et al. (2011) studied on the aggregate structure of fine textured soils and resulted that the aggregate forms pore network with relatively large continuous and interconnected intra aggregate pore space between the textural grains influences on the thermal conductivity.

Kodide (2010) showed that coarse aggregates have more thermal conductivity in compare to other aggregates because coarse aggregates have high heat absorption or heat. A cylindrical soil samples measured thermal conductivity was high at the bottom of the cylinder and low at the top portion of the cylinder. Kohout and Collier (2004), Tarnawski and Leong (2000) and Lipiec and Hatano (2003) studied about the factors that influence on the thermal conductivity and resulted that water content and bulk density influence on both thermal conductivity and penetration resistance is significant.

Kim et al. (2013) and Tien et al. (2005) analyzed relationships between thermal conductivity and volumetric water content. Although the other researchers indicated the thermal conductivity decreasing by volumetric water content reducing. Kim et al. (2013) contemplated that this relationship might be as a result of soil–water characteristic curve (SWCC). Abu-Hamdeh (2003) studied different factors effects on the soil thermal conductivity that can be managed externally and contains water content and soil compaction.

Aggarwal et al. (2009) and Maity and Aggarwal (2012) indicated that water content plays a major role in a soil thermal conductivity. Water content is the most difficult to manage. They resulted by soil water content management can be play an important part in determining of thermal conductivity. Signorelli et al. (2007) investigated the underground thermal conductivity by using of a thermal response test that was more applied for measuring the thermal properties position.

Hamuda (2009) suggested standard steady state laboratory tests for measuring soils thermal conductivity, but there are a few standard tests for determination thermal conductivity property (ASTM 518). Xaman et al. (2009) used laboratory techniques for soil thermal conductivity measurement as two main categories. The first group includes steady state methods. The second group includes unsteady methods that measure the thermal conductivity during a transient state.

The needle probe equipment is the only standardized transient method for measuring soils thermal conductivity (ASTM 5334). Wang et al. (2010) performed the testing rig of heat and moisture transfer method in soil under high-temperature condition and thermal storage and estimated about water content relationship with thermal properties. Tan et al. (2006) and Clarke et al. (2008) studied about steady state methods and resulted this method needs to the long time to reach the steady state condition and moisture migration. Nusier and Abu-Hamdeh (2003) used the dual-probe heat-pulse technique for measuring soil thermal properties. They showed that this technique consists of two parallel needle probes separated by a distance

Zhang et al. (2017) tested the thermal needle probe and resulted that this technique is explained as the linear heat transfer principle. By this method, heat conduction Fourier's law is using for thermal conductivity calculation. Ciocca et al. (2012) indicated that active measuring method uses heat pulse to measure soil thermal conductivity. The used line heat source considers line-shape and it can be shown as an infinitely long line source of infinitesimal radius. Low et al. (2013) did thermal conductivity measurement by using of the needle probe method according to the Carslaw and Jaeger theory (1959) as thin line heat source and gained new results about thermal conductivity measurement data.

Jackson and Taylor (1965) and Campbell et al. (1991) studied on the thermal conductivity and resulted that thermal conductivity can be determined according to the temperature measurements or by using of the heat-pulse probe. Bristow et al. (2001) and Ren et al. (1999) developed thermal probe that lets to soil thermal properties, water content and electrical conductivity simultaneous measurement and it is sufficient for using at the near of soil surface or at the near of roots as a result of its small size. de Vries (1952, 1963) indicated the models to predict thermal conductivity and volumetric heat capacity of soils by using of the volume fractions of their constituents and the shape of the soil particles.

de varies (1963) model basic is as physically model and has been used in different researches that have shown the soil temperature changes and thermal conductivity relationship (Campbell *et al.* 1994). Votrubova et al. (2012) and Loukili et al. (2008) investigated the effect of simulated thermal regime by the effect of different estimates of water thermal conductivity relationship in the soil profile. Farouki (1981) studied about thermal conductivity model and experimental measurement of thermal conductivity and summarized estimation of soil thermal conductivity on models or on experimental data. Goodrich (1986) and Overduim et al. (2006) measured the active layer soils thermal conductivity at four Canadian locations by using of a transient heat pulse probe and computed the different layers thermal conductivity by this prob.

Kersten (1952) considered on the effect of dry density and water content on thermal conductivity and explained the semi-theoretical and semi-experimental model. Omar (1981) calculated the soils thermal conductivity by investigating the impact of the saturation degree and reported a linear relationship between water content and thermal conductivity. Cehn et al. (1992) offered method according to the at least heat resistor principle and the effective thermal conductivity principle for calculating the complex material effective thermal conductivity.

Vlodek and Bernhard (1993) suggested application model to estimate soil thermal conductivity quickly according to the lognormal aggregate size distribution as de-Vries model basic. Liu et al. (2002) resulted simple sufficient soils thermal conductivity prediction model by inner test that it subtended two basic porosity and saturation variables. Hu et al. (2001) used of limited element model and distinguished the temperature and heat flux and analyzed the different saturation condition effect on thermal conductivity according to the moisture migration.

Li et al. (2007, 2009) studied about soil details thermal conductivity and simulated the relationship between geotechnical material thermal conductivity and its porosity according to the 3 dimension steady heat conduction models. Tan et al. (2010) and Pei et al. (2013) researched application cases and several models special properties by calculating the thermal conductivity during freeze-thaw cycle and provided information for thermal conductivity calculation under low temperature condition by attending phase change condition.

Horton (2002) defined thermal parameters by heat conduction model and reported that heat conduction as a result of conduction and convective heat transfer ought to be as external thermal properties sort of real conduction parameters. Haung et al. (2014) studied about soil depth and temperature variation and resulted that depth increasing induce to average soil temperature rising. de Vries (1963) offered a soil thermal conductivity model according to Maxwell’s equations for the uniform spheres dispersed electrical conductivity within a steady fluid current. Gori and Corasaniti (2002) indicated the thermal conductivity increasing effects of the air phase according to humidity in the model and improved its application under high temperature condition.

Haigh (2012) extended an analytical solution by studying the unilateral heat flow by a three-phase soil element. Some soil thermal conductivity predictive models had been expanded base on the empirical fits to experimental data of natural soils (Kersten 1949; Johansen 1975; Donazzi *et al.* 1979; Gangadhara Rao and Singh 1999; Cehn 2008; Cote and Konrad 2005; Lu *et al.* 2007). Kersten (1949) executed laboratory experiments to measure the natural soils thermal conductivities and suggested an empirical relationship among thermal conductivity and water content and dry bulk density.

Johansen (1975) offered normalized thermal conductivity principle to evaluate soil type, porosity, degree of saturation and mineral component impacts on soil thermal conductivity. They explained thermal conductivity according to degree of saturation condition. Zhang et al. (2016) offered new soil thermal conductivity model for sand-clay mixtures thermal conductivity prediction by using of the thermo-TDR probe and to normalize thermal conductivity. Chen (2008) studied on the soil thermal conductivity models and developed thermal conductivity model for sands with high quartz content.

Zhang et al. (2015) researched about the soil different details thermal conductivity and estimated net quartz sands thermal conductivity and developed Cote and Konrad (2005) model. Balland and Arp (2005) studied about the organic matter relationship with thermal conductivity and evaluated the models about this matter and modified Johansen

(1975) model for denoting the impact of organic matter on thermal conductivity of solid.

Donazzi et al. (1979) and Gangadhara Rao and Singh (1999) fixed the relationships among thermal resistivity and porosity, degree of saturation, dry density and moisture content according to the laboratory experiments. They indicated thermal conductivity model that was prepared according to the thermal conductivity and resistivity correlation results.

de Vries (1963) studied about the soil details thermal conductivity and tried to indicate the soil different segment thermal conductivity and presented the weighted average thermal conductivity model of soil matrix components that was modified by using of the Maxwell equation. Gori (1983) studied about soil water content and thermal properties and suggested soil cubic model for evaluating the impacts of water layer and pons around soil particles on heat transfer process.

Haigh (2012) studied about sand thermal conductivity and indicated a thermal conductivity model for sands according to three-phase soil contact element. The model indicated higher prediction exactitude sands amount in compared to other models. Dong et al. (2015) studied acute revision of soil thermal conductivity predictive models under unsaturated soils condition and indicated the equation to predict the thermal conductivity. Lu and Dong (2015) studied on the soil type dependency for prediction thermal conductivity and suggested an equation as soil-water retention mechanisms to overcome the model existed errors.

Gawin et al. (1996) evaluated the soil thermal models and suggested a fully coupled model as physical model and simulate heat slow transient process, water and gas from saturated to dry conditions. Campbell et al. (1994) tested different soils thermal conductivity under temperature different range condition and offered thermal conductivity models. Liu et al. (2011) used of thermal needle probe and performed experiments to measure silty clay and fine sands thermal conductivities and modified

Campbell (1994) model (1994). Smits et al. (2013) and Hiraiwa and Kasubuchi (2000) resulted that sandy soils thermal conductivity will be increased by the soil temperature raising extremely and indicated new model (Jiao *et al.* 2001; Lu uand Ren 2007; Yan *et al.* 2000; Zhang *et al.* 2009, Zhao *et al.* 1995). Thermal conductivity predictive models as,

a) Theoretical models are such as

de Vries (1963) model supposed soil solid particles were uniformly distributed in continuous pore fluid in soils and suggested a theoretical soil thermal conductivity model.

Johansen (1975) indicated Geo-Mean model and suggested a geometric mean method to predict soil thermal conductivity.

Tong et al. (2009) model evaluated the thermal conductivity of multiphase porous media and suggested a generalized thermal conductivity model on the base of the water content, porosity, degree of saturation, temperature and pressure impacts.

Haigh (2012) model is a theoretical thermal conductivity model for sands from a three phase soil contact unit cell.

b) Empirical models such as

Kersten (1949) model measured the different soils thermal conductivities and were analyzed the temperature, density, water content, degree of saturation, soil texture and mineralogy impacts on soil thermal conductivity.

Johansen (1975) model suggested a concept of normalized thermal conductivity (Kr) that is known as Kersten number.

Cote and Konrad (2005) model suggested a new Kr-Sr relationship incorporating a parameter K to evaluate for soil type impact.

Gangadhara Rao and Singh (1999) used of the laboratory tests to measure different soils thermal resistivity by using of thermal needle method and proposed soils thermal resistivity and moisture content and dry density relationship.

Midttomme (1998) model: Midttomme (1998) explained the particle size effect on thermal conductivity of quartz sands. According to the thermal test results of saturated quartz sands, he suggested thermal conductivity and sand median particle size empirical relationship. Zhang et al. (2016), Chen (2008) and Haigh (2012) showed relatively high prediction accuracy among the thermal conductivity selected models. They studied about the accuracy about the different soil thermal conductivity models and offered models about soil thermal conductivity.

Gangadhara Rao and Singh (1999), Donazzi et al. (1979) and Kersten (1949) models cannot predict sand thermal conductivity exactly and the performance of other models is in the medium range. Zhang and Wang (2017) studied on the quartz content effect on soil thermal conductivity and considered that quartz content should be paid attention for the model prediction. Luikov (1996) and Philip and Vries (1957) showed a moisture transposition model at in-homogeneous temperature profiles that temperature variation and trend effects on moisture transposition.

Li et al. (2005) studied about the different factors effects on the soil thermal conductivity and indicated an inner heat source model that was as a result of moisture transposition in soil, soil type and soil porosity. Liu et al. (2005) improved a model to evaluate water evaporation, temperature and water temporary distributions in the porous soil with a dry surface layer at environmental conditions.

Zhao et al. (2008) performed an experimental study to evaluate the saturated soil thermal application to indicate a model. They used of the soil texture and moisture content and peak temperature and peak volumetric water content for this research. Donazzi et al. (1979) evaluated the soil thermal and hydrological and suggested an empirically derived model.

Cote and Konrad (2005) modified Johansen's model to remove saturation ratio effects under low degrees of saturation condition. Also, they proposed three empirical parameters to indicate the particle shape and soil texture impact. Lu et al. (2007) improved Johansen's model and proposed several empirical parameters for sandy soils. Chen (2008) studied the thermal conductivity models and suggested an empirical model according to the needle-probe tests results on sands. Soil thermal conductivity was calculated by using of the analytical model of the heat conduction equation (Shiozawa and Campbell 1990).

Barik (1998) evaluated the heat properties changes during soil profiles depth as a function of soil moisture for prediction soil heat characteristics and resulted thermal conductivity of upper soil layers increased both dry and saturation condition and saturation condition thermal conductivity value rising was more than dry condition. Also, he indicated that soil moisture increased thermal conductivity and the volumetric heat capacity increased. Thermal diffusivity increased in dry condition up to pF 4,2 and decreased after this point.

Canbolat and Barik (1998) used of the mathematical models to evaluate soil thermal properties changes as a function of soil moisture and resulted that soil thermal conductivity increased significantly from dry to moist conditions. But, there were non significant differences in thermal conductivity between moist and saturated conditions Almost a perfect linear relationship was obtained between volumetric heat capacity and volumetric moisture content. Thermal diffusivity increased from dry to moist conditions, but decreased after that.

Ekberli et al. (2005) investigated heat balance in soil as related with theoretical and experimental examination of heat transfer effects on plant growth and indicated that to explain the soil heat balance should be evaluated some soil thermo-physical properties such as, Albedo constant (α), heat capacity (C), heat conductivity constant (λ) and thermal diffusivity (a_2) with other factors affecting them. So, some factors such as, soil moisture and mineralogy affecting thermo-physical properties must be known. To determine the heat balance in different soil layers, diffusivity constant can be determined for each soil layer individually using amplitude changes in soil surface and layers. Ekberli et al. (2015) evaluated the one dimensional heat conductivity equation in case of instant heating and cooling soil surface conditions and indicated the prediction of changes in soil temperature along soil profile using the solution has been also shown on a numerical example.

Yılmaz (2008) determined thermal properties of soils with mathematics model by using of physical and chemical characteristic and resulted that this model is useful for the determination of soil temperature regime. Şımarmaz (2010) determined thermal properties of soils by using of physical and chemical characteristic in mathematics models and resulted there was harmonious relations between mathematics models of heat transmission and measurement values. So, it was found that these models are useful for the determination of soil temperature regime.

Sarılar (2013) investigation of temperature changes and some thermal properties of soils and indicated that the relative error between soil temperatures estimated from the solution of heat transfer equation and daily measured soil temperatures were determined between 0.015 and 0.089. Ekberli et al. (2017) predicted daily soil temperature change in different soil depths of 0-50 cm soil layer depend on heat diffusivity coefficient values and found that daily soil temperature changes in different soil depths can be predicted by using of the heat diffusivity coefficients determined with parabolic function. Ekberli and Sarılar (2015) determined the damping depth and retardation time of soil temperature along soil profile and resulted that soil temperature, heat diffusivity coefficient, amplitude and frequency of heat waves together with other environmental factors have significant effects on damping depth and retardation time.

3. MATERIALS and METHODS

This chapter provides descriptions of the study area and laboratory experiment design. It also delivers detailed depictions of laboratory analytical methods that were used in this study to perform the analyses and estimate and evaluate different soil aggregate size properties. Statistical analyses used in this study are also described.

3.1. Materials

3.1.1. Soils

Experiments were performed on soil samples with different textures (fine textures soil (FTS), medium textures soil (MTS) and coarse textures soil (CTS)). The soil samples were taken of three regions of Erzurum, Turkey with the name and geographical coordinates, Daphan plain (40° 10′ 12″ N and 41° 42′ 16″ E) with Typic Ustert great group of soil taxonomy , Yarimca village (39° 59′ 32″ N and 41° 28′ 53″ E) and the region of north west of Ataturk university Agriculture faculty (39° 58′ 26″ N and 41° 29′ 02″ E) with Calciorthid and Fluvaquent great group of soil taxonomy, respectively. Each sampling level was between 0-20 cm soil depths.

3.1.2. Site Description

Erzurum is located between 39° 10'- 40° 57' Northern latitudes and 40° 15'- 42° 30' Eastern longitudes in Eastern Anatolia region. Erzurum Province has been surrounded by Artvin-Rize from the north, Ardahan from the northeast, Gümüşhane-Erzincan from the west, Bingöl-Muş from the south, Ağrı-Kars from the east. The province has a surface area of 24768 km^2 and the central province has an area of 2892 km^2.

Terrestrial climate features predominate in Erzurum. The average temperature of the coldest months is -13,9°C, the highest temperature average is 27,1°C, the coldest month's average temperature is -9,1°C, the warmest month's average temperature is 19,5°C, and average annual air temperature is 5, 7°C . Annual precipitation is 432,8 mm. Annual evaporation is 987,2 mm, average relative humidity is 63,9%, average number of frost days is 112 days (Table 3.1). The first frost occurs in late October and the last frost in mid-April (Anony 2018).

Table 3.1. The average climate data of Erzurum province for many years (1929-2016) (Anony. 2018)

Parameter	Jan.	Feb.	Mar.	Apr.	Ma.	Ju.	Jul.	Aug.	Sep.	Oc.	Nov.	Dec.	Annual
Average Temp. (°C)	-9,1	-7,7	-2,5	5,3	10,7	14,9	19,3	19,5	14,7	8,1	1	-6,0	5,7
Average. Max. Temp. (°C)	-4,0	-2,4	2,4	10,9	16,8	21,7	26,4	27,1	22,6	15,1	6,8	-1,1	11,90
Average. Min. Temp. (°C)	-13,9	-12,6	-7,2	0,1	4,4	7,4	11,2	11,2	6,5	1,8	-3,6	-10,3	-0,4
Monthly Total Precipitation Average (mm)	22,5	27,3	35,0	53,5	73,1	49,1	26,8	17,5	23,90	48,2	33,3	22,6	432,8
Average Relative humidity, %	76,2	75,2	74,2	65,3	61,2	56,3	50,3	47,5	50,3	61,5	72,2	76,5	63,9
Average Evaporation, mm	0,0	0,0	0,0	11,3	119,1	160,9	237,9	235,8	168,6	55,3	0	0	987,2

3.1.3. Synthetic Organic Polymer-Polyvinyl Alcohol (PVA)

Polyvinylalcohol (PVA) as synthetic organic polymer was used in the experiment that its some physical and chemical properties were given in Table 3.2.

Table 3.2. Used polyvinyl alcohol (PVA) properties

Form	Granular
Color	White
Hydrolysis, mole %	87-89
Saponification number	3-12
Residual polyvinyl acetate, weight %	0,5-1,5
Viscosity, mPa.s	27-33
Solution pH	5-7
Volatiles, % max	5
Ash (as Na_2O), % max	1
Bulk density (kg/m^3)	400-432
Specific gravity	1,30
Average molecule weight (g/moll)	146000-186000
Specific heat J/kg.K	1674

3.2. Methods

3.2.1. Soil Chemical Properties

Some chemical analysis such as pH, electrical conductivity, organic matter, lime, N, P, K amounts and cation exchange capacity was done for soil samples. These measurements were done according to following methods:

pH was measured as potansiometric with glass electrodes of pH meter into the suspension with 1:2.5 ratio (Mc Lean 1982); EC, by preparing the extraction of the saturation mud and reading by the EC meter as mmhos cm^{-1} (Richards 1954); organic material with Smith-Weldon method (Nelson and Sommers 1982); lime content (mineral CO_2) was determined with the Scheibler calsimeter, then the mineral CO_2 amount was used to volumetric method to calculate the lime amount (Nelson 1982); total nitrogen by using of Kjeldahl method (Bremner and Mulvaney 1982); phosphorus by using of Sodium Bicarbonate Method (Olsen and Sommers 1982); extractable potassium by using of Ammonium Acetate Method (Thomas 1982) and CEC by using of Ammonium Acetate Method (Rhoades 1982a**).**

In this experiment, were used 3 soil groups that included fine, medium and coarse texture. Each sample was air dried for 10 days and then sieved by 4 mm sieve to the next experiment stages. Each soil with different texture samples was sieved by different sieves sizes and separated to sub-groups such as 4-2 mm, 2-1 mm, <4 mm, <2 mm and <1 mm and was prepared for the analysis and the tests. Also, two treatments were performed in this experiment as control and PVA.

PVA solution was prepared under 70°C with dose ratio as %0,05 w/w and was applied as spray on the soil samples. This ratio was matched with the soil sample amount that used for every test. To prevent the losses of the solution from the soil and debarment of solution evaporation, soil samples were covered by the black plastics and were kept under laboratory temperature as incubation during 48 hours. After this period, the plastics were opened and soil samples were dried as air dry condition.

This experiment was done as three replications and analysis such as aggregate stability, air permeability, pF, dispersion ratio, hydraulic conductivity, particle size distribution, bulk density (ρ_b) and particle density (ρ_p) were studied as factorial under complete randomized design.

This experiment was measured soil thermal properties such as thermal conductivity, heat capacity and thermal diffusivity under experimental condition and was calculated as modeling.

3.2.2. Particle Size Distribution (PSD)

Soil particle size distribution analysis was performed by using the Bouyoucos, Day and sieving methods as described by Day (1965) and Gee and Bauder (1986). There were three soil textures in this study according to the sampling region. Daphan region soil texture was clay, Yarimca village region soil texture was loam and Ataturk university Agriculture faculty area soil was sandy loam.

The soil particle size distribution curves that prepared by Day and sieving methods. For Day method performance was used of 40 g air dry soil sample with different aggregate size (<4 mm, 4-2 mm, <2 mm, 2-1 mm and <1 mm). On the soil samples were added 200 ml pure water and 50 ml sodium hexametaphosphate (%10). Then mixed the materials on the shaker during 2 hours. After shaking, the suspension has been passed of the 0,1 mm sieve and the suspension sample was separated to two samples as bigger as and smaller than 0, 1 mm sizes (Day, 1965). After this stage there were two processes:

The compound on the 0,1 mm sieve was dried in oven and then is sieved by sieves series with 2; 1; 0,5; 0,25 and 0,1 mm sizes according to the soil aggregates sizes (<4 mm, 4-2 mm, <2 mm, 2-1 mm and <1 mm) and was weighted each fraction on the every sieve.

The passed compound of the 0,1 mm sieve was removed into the sedimentation cylinder for measuring by Day hydrometer method that the final volume of the suspension into the cylinder was completed to the one liter by pure water. A blank solution in a separate 1000 ml graduated cylinder was used to account for the sodium hexametaphosphate added to the suspension. This blank was prepared with 50 ml of sodium hexametaphosphate (%10) and was brought up to 1000 ml volume with deionized water. The suspension into cylinder after mixing was read by hydrometer as series reading at 0,5; 1; 3; 10; 30; 90; 270; 720 and 1500 minutes and similar reading that belonged to the temperature changes was done for the blank solution, too. Also, one soil subsample was taken to measure the soil moisture content at the starting of the test.

At the end, particle size distribution curve was drawn according to the results date that measured by Day hydrometer and sieving methods that X axis includes particle size (diameter) as mm and Y axis includes particle weighted percentage. By using of the particle size distribution curves that was drawn for <4 mm; 4-2 mm; <2 mm; 2-1 mm and <1 mm aggregate sizes, separately and was determined clay, silt and sand percentage for the each soil samples.

3.2.3. Moisture Tension Curve

For each aggregate size fraction was drawn the moisture tension curve. Soil samples was located into brass cylinder (5 cm × 5 cm) and settled on the ceramic plate and the plate and soil samples received to the saturation condition by capillary wetting. The soil samples into the cylinders were weighted under the saturated condition and then the cylinders and ceramic plate was settled the pressure extractor. After treating 0,005 and 0,033 Mpa air pressure that are equal with 1,7 and 2,54 pF on the soil samples into the extractor and receiving to the hydraulic balance under these pressures was weighted the wetted weights and over dry weights (105°C) and calculated the gravimetric moisture percentage. For determining the permanent wilting point was treated 1,5 MPa air pressure on the soil samples. After receiving to the hydraulically balance was weighted the moisture samples and then determined the weight of the dried samples at the (105°C) of oven. By these values was founded the soil moisture content according to the 1,5 MPa pressure. After calculation the gravimetric and volumetric moisture for each soil sample, the pF curve was drawn that X axis was the Pw (sample moisture weighted percent) and Y axis was the pF amount that was applied for the samples at each stage (Cassel and Sweeney 1974; Demiralay 1993).

3.2.4. Bulk Density (ρ_b)

In this method, the cylinder (5×5 cm) was filled with distributed soil sample and the soil sample settled was done by free falling from 2,5 cm height. The cylinder volume was filled according to the soil oven dry weight and finally accounted the bulk density belong to the details.

$$\rho_b = \frac{ms}{Vt}$$

ρ_b: bulk density, g/cm^3
m_s: mass of dry soil sample, g
V_t: soil total volume, cm^3

3.2.5. Particle Density (ρ_p)

Particle density was determined by using of the pycnometer method (Blake and Hartge 1986a).

3.2.6. Aggregate Stability

The wet aggregate stability is determined by using of wet sieving on the base of the follow equation (Kemper and Koch 1966; Kemper and Rosenau 1986).

$$A.S. = \frac{P1-P2}{P-P2}\times 100$$

A.S.: aggregate stability, %
P_1: stable aggregate + sand, g
P_2: sand,
P: oven dried soil, g

3.2.7. Dispersion Ratio

Dispersion ratio (Middleton 1930) measures the degree of water stable aggregation of the silt and clay fraction of the soil. In this test the extent of natural dispersion of clay particles is compared with that obtained with the use of standard chemical and mechanical dispersion. Under undispersed condition means that direct measurement with hydrometer into the suspension without any chemical or physical dispersion. Dispersion soil at mechanic analysis means the reading of the soil texture experiment by hydrometer after physical and chemical dispersion (Bryan 1968; Lal 1988).

Dispersion ratio was calculated by using of the follow equation.

$$\text{Dispersion ratio (DR)} = \frac{[(\%\, silt + \%\, clay)\ in\ undispersed\ soil]}{[\ (\%\, silt + \%\, clay) after\ dispersion\ of\ soil\ in\ water\ at\ mechanic\ analysis]}$$

Dispersion ratio greater than 0,5 are considered highly dispersive, between 0,3 and 0,5 are moderately dispersive, between 0,15 and 0,3 are slightly dispersive and less than 0,15 are non-dispersive (Walker 1997).

3.2.8. Hydraulic Conductivity

The constant-head test with the permeameter is one of the most commonly used methods for determining the saturated hydraulic conductivity of soils in the laboratory. The test operates in accordance with the direct application of Darcy's law. In this method, a cylindrical soil sample of cross-sectional area A (cm^2) and length L (cm) is placed between two porous plates that do not provide any extra hydraulic resistance to the flow. A constant head difference, H_2 - H_1,(cm) is then applied across the test sample (Klute and Dirksen 1986). By measuring the volume Q (cm^3) of the test fluid that flows through the system during time t (hr), the saturated hydraulic conductivity K (cm/hr) of the soil can be determined directly from Darcy's equation:

$$K = \frac{Q\ L}{(At\ (H2-H1))}$$

3.2.9. Thermal Conductivity

This experiment was measured soil thermal properties such as thermal conductivity, heat capacity and thermal diffusivity under experimental condition and was calculated as modeling. The thermal conductivity measurements that were done in the research will be given as following:

Thermal needle probe thermal properties analyzer that was designed by the Prof. Dr. Hasan Efeoglu (Professor of Engineering Faculty, Electronic department of Ataturk University) was used to record all thermal properties of the soil. The needle probe was made of stainless steel tube with 6 mm outer diameter, 4 mm inside diameter and 240 mm length which gave a length to diameter ratio of 40 to eliminate the error due to finite size of the heating element. A nickel-chrome heating wire with 0,2 mm diameter and 24 cm length is placed inside the tube and connected to the DC power supply. The temperature sensor was calibrated from 4 to 81°C using a thermocouple equipped with a temperature controller model REX-P250. When the sample temperature reached the equilibrium the heater wire was energized by the regulated DC power supply with a 0-30 V and 0-3 A to make heat transfer at radial direction from the probe into surrounding sample. The thermal conductivity measurement system has three components: the thermal conductivity probe (which includes a temperature sensor and a heating wire, a DC power supply for the heater wire inside the probe and a personal computer equipped with a data logger system for reading and recording the temperature values of the sample (Kara *et al.* 2011).

Each soil with different texture samples was sieved by different sieves sizes and separated to sub-groups such as <4 mm, 4-2 mm, <2 mm, 2-1 mm and <1 mm and was prepared for determining the soil thermal properties. Samples thermal conductivity was calculated with temperatures data that was measured by thermal needle probe under air dry and different moisture conditions. Soil samples that belonged to each aggregate size fraction was settled to the cylinder with 15,4 cm internal diameter and 25 cm height and allowed to equilibrate at room temperature, and the probe was then located at the longitudinal axis of the holder as the dry condition. The temperature rise was recorded every minute during a period of 10 min from the moment of switching on the power supply. A constant DC power source of 5 V and 520 mA that producing 10,83 $W.m^{-1}$. This period was the heating period. The curve of temperature versus elapsed time was obtained on the monitor of PC and subsequently a thermogram was obtained plotting the temperature values. This process was as the primary stage to read the thermal conductivity under air dry condition. After the process, the samples were saturated and reading the temperatures was done as above process. After this stage, the saturated samples located into oven at 65° C to dry. The temperature readings were done during the saturation sample drying period at the oven one time daily. This process continued till the sample dry completely and there was no moisture change of the samples. Also, before each thermal conductivity measurement by thermal needle probe, the soil samples were weighted and the weights were noted. The belonged data to the each soil sample temperature were recorded by the data logger and transmitted to the computer and the results were shown as a curve. The X axis of curves was time as minute and the Y axis included the temperature changes of the soil samples during heating period.

According to the ASTM standards (D 5334-00) and (D 5334-08), thermal conductivity is determined by a variation of the line source test method using a needle probe having a large length to diameter ratio to stimulate conditions for an infinitely long specimen. Compute the thermal conductivity of the specimen from the linear portion of the experimental curve by using of the following relationship:

$$\lambda = \frac{2.30\,Q}{4\pi\,(T2-T1)}\,\mathrm{Log}_{10}\,(t_2/t_1) = \frac{Q}{4\pi\,(T2-T1)}\ln\,(t_2/t_1) = \frac{Q}{4\pi s}$$

$$Q = \frac{R\,I^2}{L} = \frac{E\,I}{L}$$

λ: thermal conductivity, W/m.k

E: measured voltage, V

I: current flowing through heater wire, A

L: length of heater wire, m

Q: power consumption of heater wire in watts per unit length, J/sec or W

R: total resistance of heater wire, Ω

T_1: initial temperature, K

t_1: initial time, sec

T_2: final temperature, K

t_2: final time, sec

s: the slope of curve

3.2.10. Volumetric Heat Capacity

Heat capacity was determined by followed equation (van Wijk and De Vries 1963).

$C_v = \rho_b (C_s + \theta_w C_w)$

C_v: volumetric heat capacity, kJ kg^{-1} K^{-1}

C_s : soil mineral specific heat, kJ kg^{-1} K^{-1}

C_w : water specific heat, kJ kg^{-1} K^{-1}

θ_w : volumetric water content, (m^3 m^{-3})

Table 3.3. Specific heat of common soil constituents, water and air at 20°C and 0,101 (1 atmosphere) (after van Wijk and de Vries 1963).

Soil Constituent	Specific heat (kJ kg^{-1} K^{-1})
Soil minerals (average)	0,73
Water	4,18
Air	1

3.2.11. Thermal Diffusivity

Thermal diffusivity (α) was determined by followed equation (Horton *et al.* 1983).

$$\alpha = \frac{\lambda}{C_v} \ (m^2 \ sec^{-1})$$

3.2.12. Modeling

In this research was used of two groups model to predict the soil samples thermal properties such as theoretical models that had two sub groups such as de-Vries (1963) and Tarnawski *et al.* (2000) and empirical models that contained two sub groups, too such as Kersten (1949) and Cote and Konrad (2005).

3.2.12.1. Theoretical Models

de Vries (1963)

Thermal conductivity was determined by de Vries model **(**Campbell *et al.* 1994).

de Vries is expressed as:

$$\lambda = \frac{KwXw\lambda w + KaXa\lambda a + KsXs\lambda s}{KwXw + KaXa + KsXs}$$

where λw, λa, and λs are the thermal conductivity of water, air and solid, respectively, xw; xa and xs are the volume fraction of water, air and solid, respectively and Kw, Ks and Ka are weighting factors depending on the shape and orientation of water, solid and air-pores, respectively and equal to,

$$K_s = \frac{1}{3}\left(\frac{2}{1+(\frac{\lambda s}{\lambda f-1})ga} + \frac{1}{1+(\frac{\lambda s}{\lambda f-1})gc}\right)$$

$$K_w = \frac{1}{3}\left(\frac{2}{1+\left(\frac{\lambda w}{\lambda f-1}\right)ga} + \frac{1}{1+(\frac{\lambda w}{\lambda f-1})gc}\right.$$

$$K_a = \frac{1}{3}\left(\frac{2}{1+\left(\frac{\lambda a}{\lambda f-1}\right)ga} + \frac{1}{1+(\frac{\lambda a}{\lambda f-1})gc}\right.$$

Where, g_a and g_c are shape factors defined by,

g_a=0,333-x_w(0,333-0,035) for 0,09≤x_w≤n

g_a=0,013+0,94x_w for 0≤x_w≤0,09

and g_c=1-2g_a

where n is the porosity and λ_f is fluid thermal conductivity.

$\lambda_f = \lambda_a + f_w\,(\lambda_w - \lambda_a)$

f_w= 1/ (1+(x_w/ x_{w0}))$^{-q}{}_1$

x_{w0}=0,267dg$^{-0,2}$

d_g=exp(0,01×∑(f_i × ln(m_i)), mm

m_i: average diameter for each particle size class, mm. (0,01, clay , 0,026, silt, 1,025, sand)

f_i: corresponding mass fraction for each particle class, %

q_1= q_0 (θ/303)^2

$q_{0=}$ 3,1

x_{w0} and q_1 are soil properties that relate to the water content at which water starts to affect thermal conductivity and rapidity of the transition from air to water dominated conductivity.

q_0 is constant and θ is the kelvin temperature of the soil (Campbell *et al.* 1994).

Tarnawski *et al.* (2000)

a) $\lambda_{dry}= \frac{(A\times\rho b)+B}{\rho p-(C\times\rho b)}$

A: 0,23; B: 64,7 and C: 0,947

ρ_b : bulk density, kg/m^3

ρ_p : particle density, kg/m^3

b) $\lambda_{sat}= (\lambda_s\times (1\text{-}n)) \times (\lambda_w\times n)$

c) $\lambda_{un\text{-}sat}= \lambda_{dry} + (K_{sat}\text{-} \lambda_{dry}) \times K_e$

$K_{sat}= ((K_{solid})^2\times(1\text{-}n)) \times (\lambda_w)^n$

$K_{\ solid}= (7{,}7^{X\ quart}) \times (\lambda_s)^{1\text{-}x\ quartz}$

K_e coarse texture soil= (0,68 log(s)+1)

K_{ev} fine texture soil= (0,94 log(s)+1)

3.2.12.2. Empirical models

Kersten (1949)

a) λ sandy= 0,1442 (0,7 log(w)-0,4)×10$^{(0,6243\times\rho b)}$

b) λ fine soil=0,1442 (0,9 log(w)-0,2)×10$^{(0,6243\times\rho b)}$

Cote and Konrad (2005)

λ= (K×S)/(1+(K-1)×S)

K= 4,6 for coarse texture soil

K= 3,55 for fine and medium texture soil

K= 1,9 for silt and clay soil

S: Saturation degree

3.2.13. Statistical Analysis

The data that were received of the soil samples properties experiments measurement were analyzed as factorial on the base of completely randomized design. The means of the data was calculated by the ANOVA method and the means were compared according to the Duncan test. Analysis was done by SPSS ver 20 software (Dowdy and Wearden 1983).

4. RESULTS and DISCUSSION

4.1. Descriptive Results

According to the Table 4.1, there were three soil textures as clay, loam and sandy loam at Daphan plain, Yarimca village and Ataturk university Agriculture faculty area, respectively.

Table 4.1. Studied soil samples general properties

Soils	Clay (%)	Silt (%)	Sand (%)	Soil texture	pH	EC (dS/m)	OM (%)	$CaCO_3$ (%)	N (ppm)	P (ppm)	K (ppm)	CEC (cmol/kg)
FTS	44	23	33	Clay	7,40	0,60	1,60	2,1	1134	25,2	37,7	51,4
MTS	23	35	42	Loam	7,46	0,44	1,48	19,3	1127	24,5	23,7	33,8
CTS	14	31	55	Sandy loam	7,11	0,30	1,82	0,9	1134	12,0	21,1	26,8

FTS: Fine texture soil, MTS: Medium texture soil, CTS: Coarse texture soil, EC: Electric conductivity, OM: Organic matter, CEC: cation exchange capacity.

The percent of organic matter was the highest at sandy loam texture soil sample and the lowest at the clay texture soil sample. Fine texture soil and medium texture soil did not have more difference as pH but the most pH included to the medium texture soil and the less pH belonged to the coarse texture soil. The most CEC was measured for the fine texture soil and the less was for the coarse texture soil. The carbonate calcium percent showed the adverse results in compare to the organic matter and the most percent was included to the medium texture soil and the less percent was belonged to the coarse texture soil. Fine texture soil had the most electrical conductivity and coarse texture soil had the less electrical conductivity. The different soil texture did not have different as nitrogen amount despite that the most nitrogen amount included to the fine texture soil and coarse texture soil. Fine texture soil had the both phosphorus and potassium amount and the less amount of these two elements belonged to the coarse texture soil.

4.2. Particle Size Distribution Curve for Aggregate Size Fractions

4.2.1. Aggregate size fraction, <4 mm

According to the Figure 4.2.1, the <2 µm particle size percent of fine texture soil <4 mm aggregate size is 26% and the particle size as 2-50 µm percent is 44%. The percents of the 50-2000 µm and 2000-4000 µm are 27% and 3%, respectively. This texture with <4 mm aggregate size well graded because all type particle represented into it. Also, according to the curve slope at the start of the curve can be resulted that the fine particles percents are high and this soil can be fine texture soil as clay.

Also, the <2 µm particle size percent of medium texture soil <4 mm aggregate size is 11% and the particle size as 2-50 µm percent is 45%. The percents of the 50-2000 µm and 2000-4000 µm are 40% and 4%, respectively. This texture with <4 mm aggregate size well graded because all type particle represented into it. This texture with <4 mm aggregate size well graded because all type particle represented into it.

The <2 µm particle size percent of coarse texture soil <4 mm aggregate size is 7% and the particle size as 2-50 µm percent is 30,5%. The percents of the 50-2000 µm and 2000-4000 µm are 54,5% and 8%, respectively. This texture with <4 mm aggregate size well graded because all type particle represented into it. This texture with <4 mm aggregate size well graded because all type particle represented into it. Also, according to the curve slope at the end of the curve can be resulted that the coarse particles percents are high and this soil can be coarse texture soil as sandy.

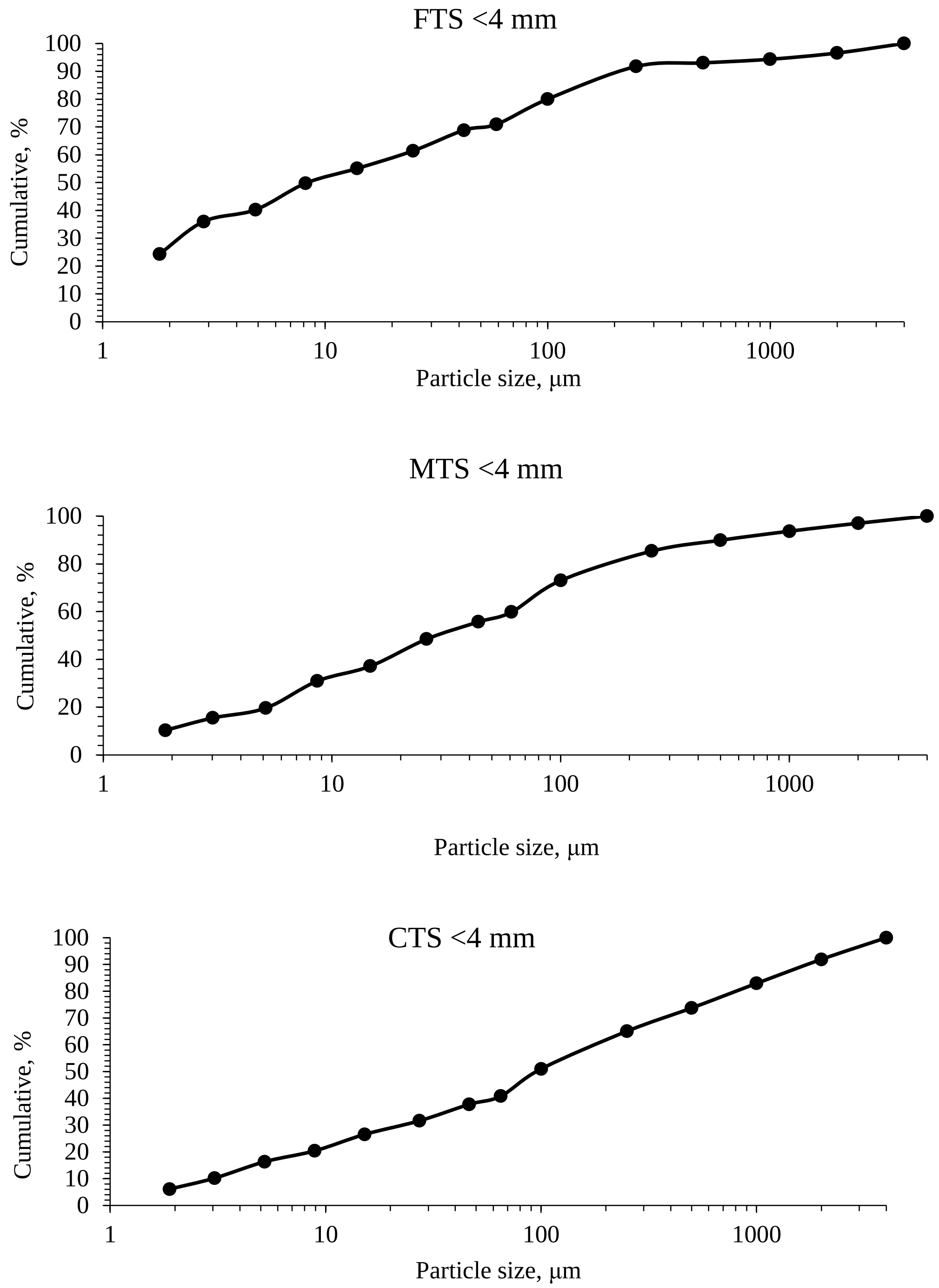


Figure 4.2.1. Particle size distribution curves for FTS, MTS and CTS <4 mm aggregate size

4.2.2. Aggregate size fraction, 4-2 mm

According to the Figure 4.2.2, the <2 µm particle size percent of fine texture soil 4-2 mm aggregate size is 18% and the particle size as 2-50 µm percent is 62%. The percents of the 50-2000 µm and 2000-4000 µm are 8% and 12%, respectively. This texture with 4-2 mm aggregate size well graded because all type particle represented into it. Also, according to the curve slope at the start of the curve can be resulted that the fine particles percents are high and this soil can be fine texture soil as clay.

Also, the <2 µm particle size percent of medium texture soil 4-2 mm aggregate size is 15% and the particle size as 2-50 µm percent is 43%. The percents of the 50-2000 µm and 2000-4000 µm are 32% and 10%, respectively. This texture with 4-2 mm aggregate size well graded because all type particle represented into it. This texture with 4-2 mm aggregate size well graded because all type particle represented into it.

The <2 µm particle size percent of coarse texture soil 4-2 mm aggregate size is 8% and the particle size as 2-50 µm percent is 19%. The percents of the 50-2000 µm and 2000-4000 µm are 32% and 41%, respectively. This texture with 4-2 mm aggregate size well graded because all type particle represented into it. This texture with 4-2 mm aggregate size well graded because all type particle represented into it. Also, according to the curve slope at the end of the curve can be resulted that the coarse particles percents are high and this soil can be coarse texture soil as sandy.

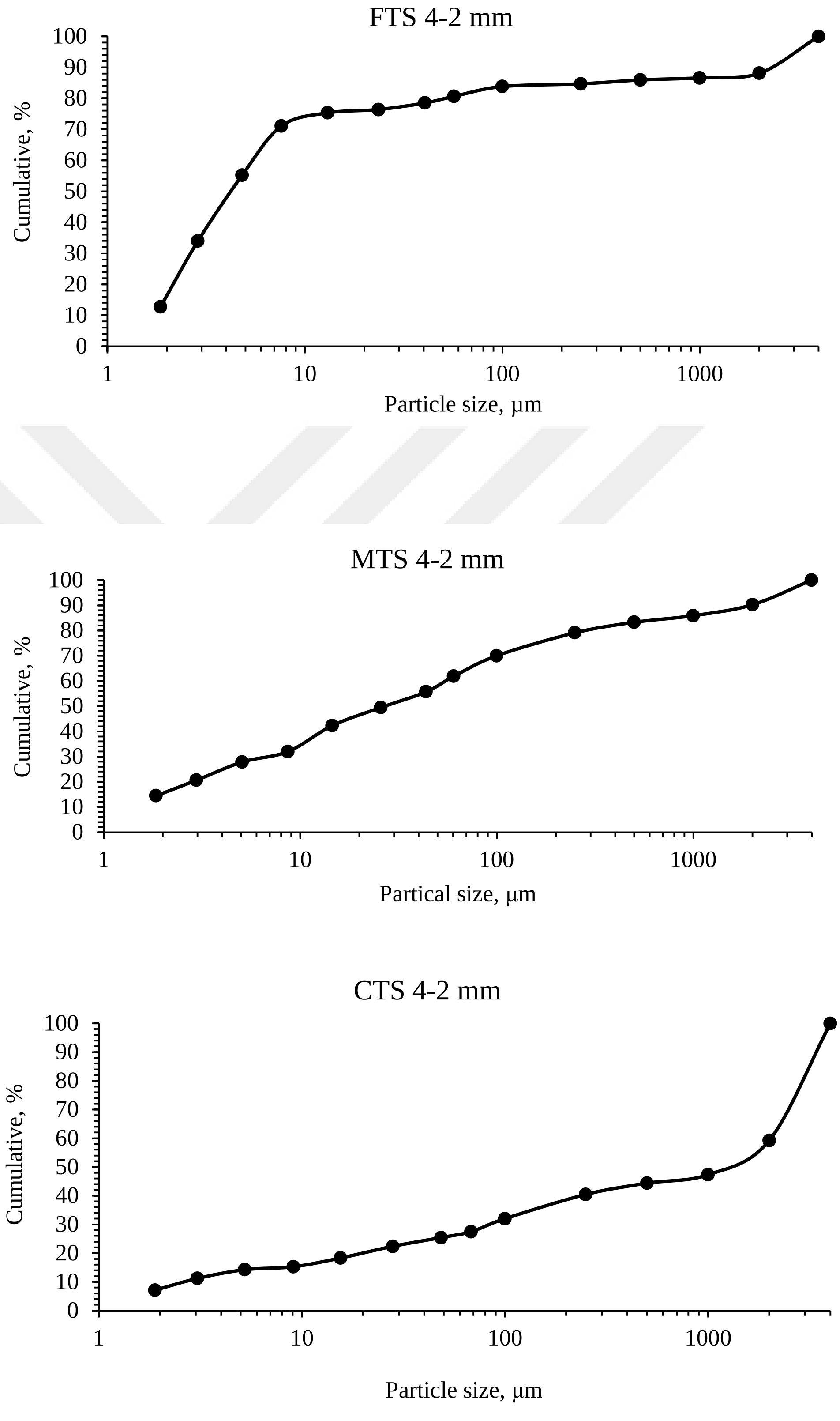


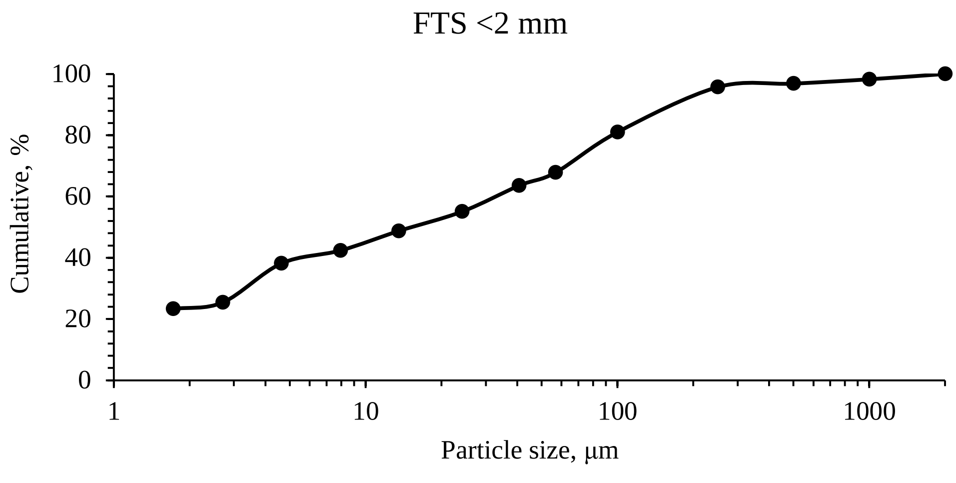
Figure 4.2.2. Particle size distribution for curves FTS, MTS and CTS 4-2 mm aggregate size

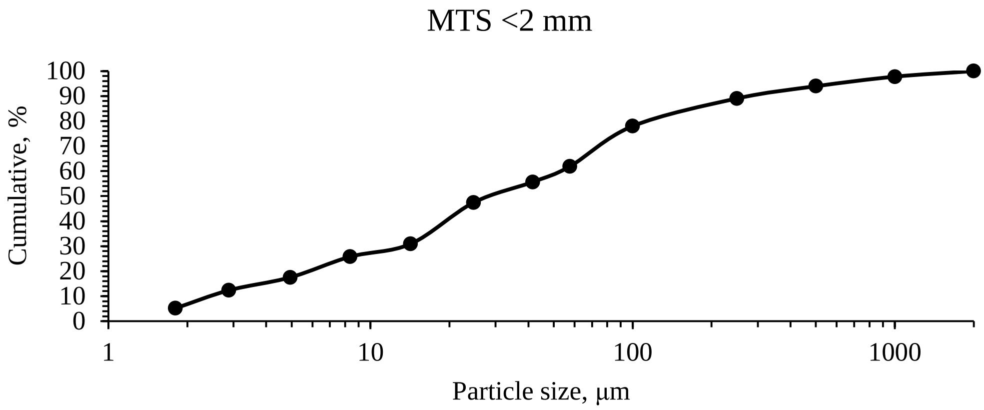
4.2.3. Aggregate size fraction, <2 mm

According to the Figure 4.2.3, the <2 µm particle size percent of fine texture soil <2 mm aggregate size is 25% and the particle size as 2-50 µm percent is 40%. The percents of the 50-2000 µm are 35%. This texture with 2-1 mm aggregate size well graded because all type particle represented into it. This texture with <2 mm aggregate size well graded because all type particle represented into it.

Also, the <2 µm particle size percent of medium texture soil <2 mm aggregate size is 7% and the particle size as 2-50 µm percent is 51%. The percents of the 50-2000 µm are 42%. This texture with <2 mm aggregate size well graded because all type particle represented into it. This texture with <2 mm aggregate size well graded because all type particle represented into it.

The <2 µm particle size percent of coarse texture soil <2 mm aggregate size is 6% and the particle size as 2-50 µm percent is 37%. The percents of the 50-2000 µm are 57%. This texture with <2 mm aggregate size well graded because all type particle represented into it. This texture with <2 mm aggregate size well graded because all type particle represented into it.





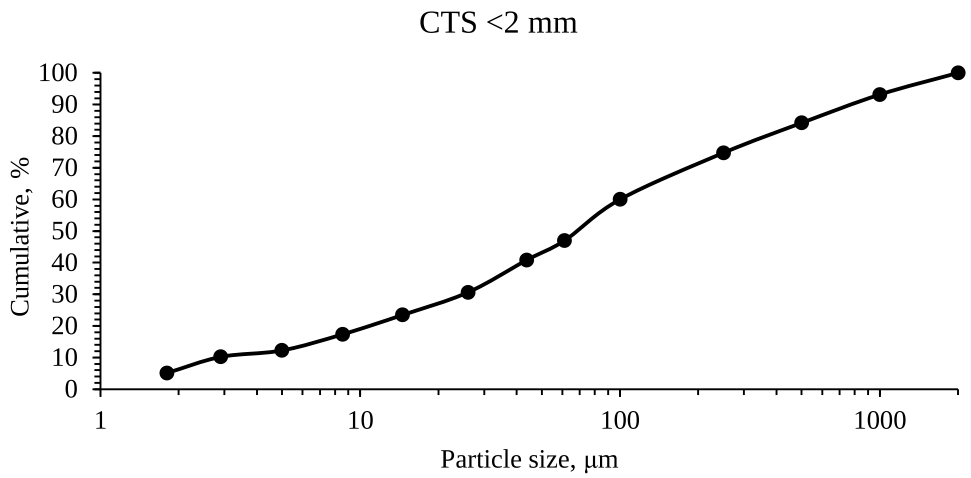


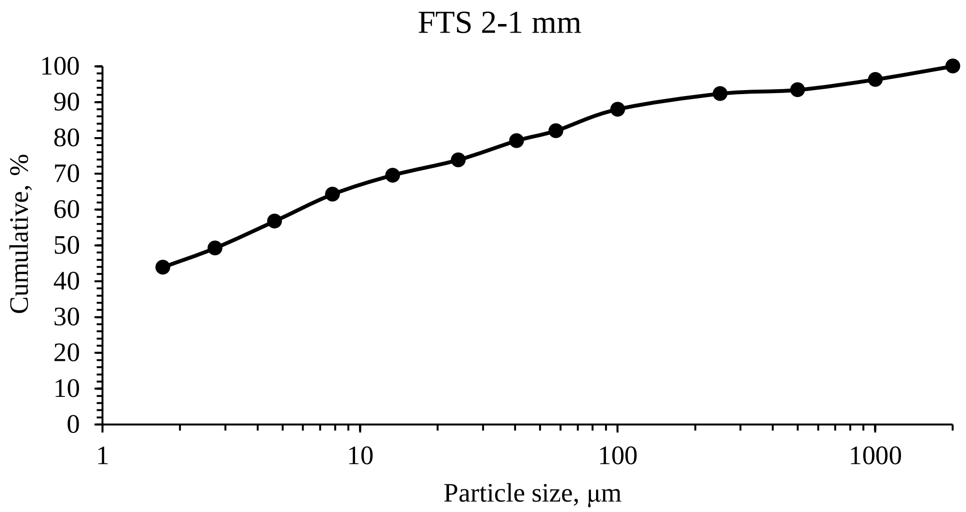
Figure 4.2.3. Particle size distribution curves for FTS, MTS and CTS <2 mm aggregate size

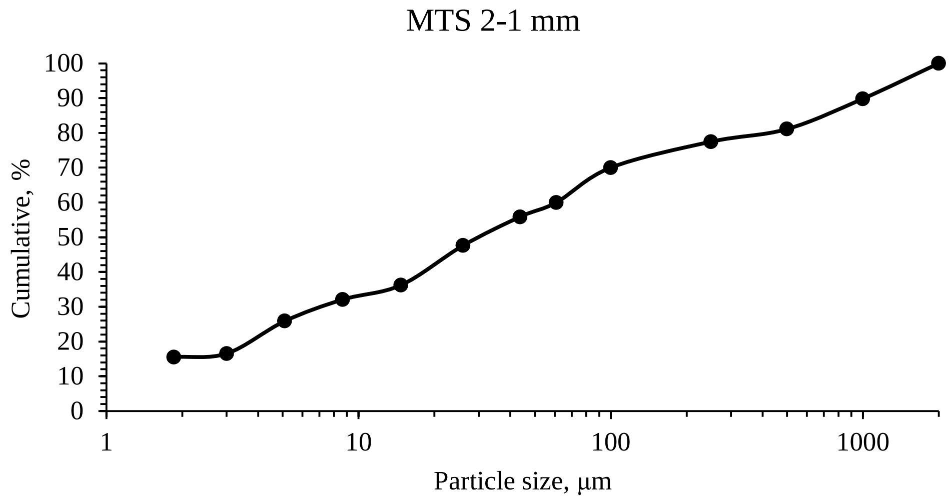
4.2.4. Aggregate size fraction, 2-1 mm

According to the Figure 4.2.4, the <2 µm particle size percent of fine texture soil 2-1 mm aggregate size is 46% and the particle size as 2-50 µm percent is 34%. The percents of the 50-2000 µm are 20%. This texture with 2-1 mm aggregate size well graded because all type particle represented into it. This texture with 2-1 mm aggregate size well graded because all type particle represented into it.

Also, the <2 µm particle size percent of medium texture soil 2-1 mm aggregate size is 16% and the particle size as 2-50 µm percent is 42%. The percents of the 50-2000 µm are 42%. This texture with 2-1 mm aggregate size well graded because all type particle represented into it. This texture with 2-1 mm aggregate size well graded because all type particle represented into it.

The <2 µm particle size percent of coarse texture soil 2-1 mm aggregate size is 10% and the particle size as 2-50 µm percent is 32%. The percents of the 50-2000 µm are 58%. This texture with 2-1 mm aggregate size well graded because all type particle represented into it. This texture with 2-1 mm aggregate size well graded because all type particle represented into it.





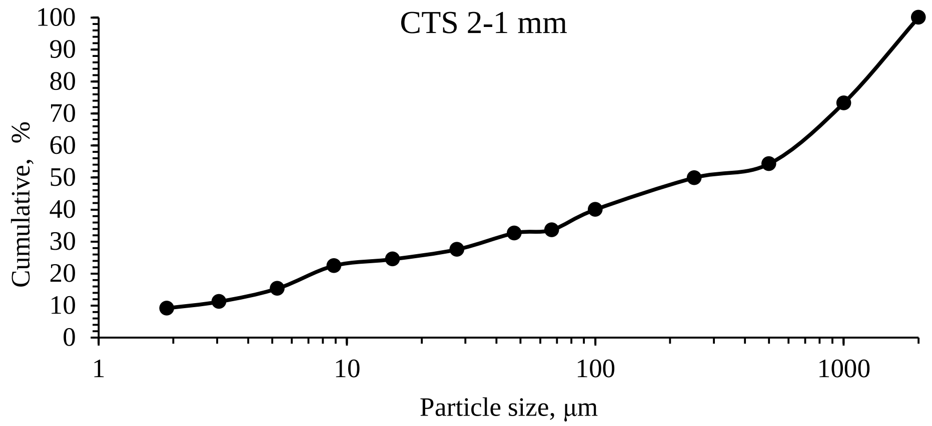


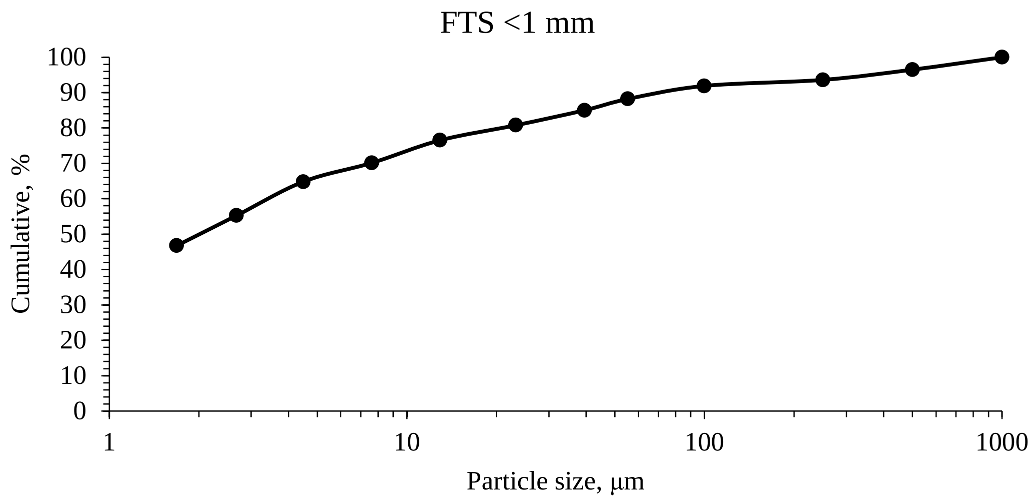
Figure 4.2.4. Particle size distribution curves for FTS, MTS and CTS 2-1 mm aggregate size

4.2.5. Aggregate size fraction, <1 mm

According to the Figure 4.2.5, the <1 µm particle size percent of fine texture soil <1 mm aggregate size is 50% and the particle size as 2-50 µm percent is 37%. The percents of the 50-1000 µm are 13%. This texture with <1 mm aggregate size well graded because all type particle represented into it. This texture with <1 mm aggregate size well graded because all type particle represented into it.

Also, the <1 µm particle size percent of medium texture soil <1 mm aggregate size is 18% and the particle size as 2-50 µm percent is 42%. The percents of the 50-1000 µm are 40%. This texture with <1 mm aggregate size well graded because all type particle represented into it. This texture with <1 mm aggregate size well graded because all type particle represented into it.

The <1 µm particle size percent of coarse texture soil <1 mm aggregate size is 12% and the particle size as 2-50 µm percent is 30%. The percents of the 50-1000 µm are 58%. This texture with <1 mm aggregate size well graded because all type particle represented into it. This texture with <1 mm aggregate size well graded because all type particle represented into it.



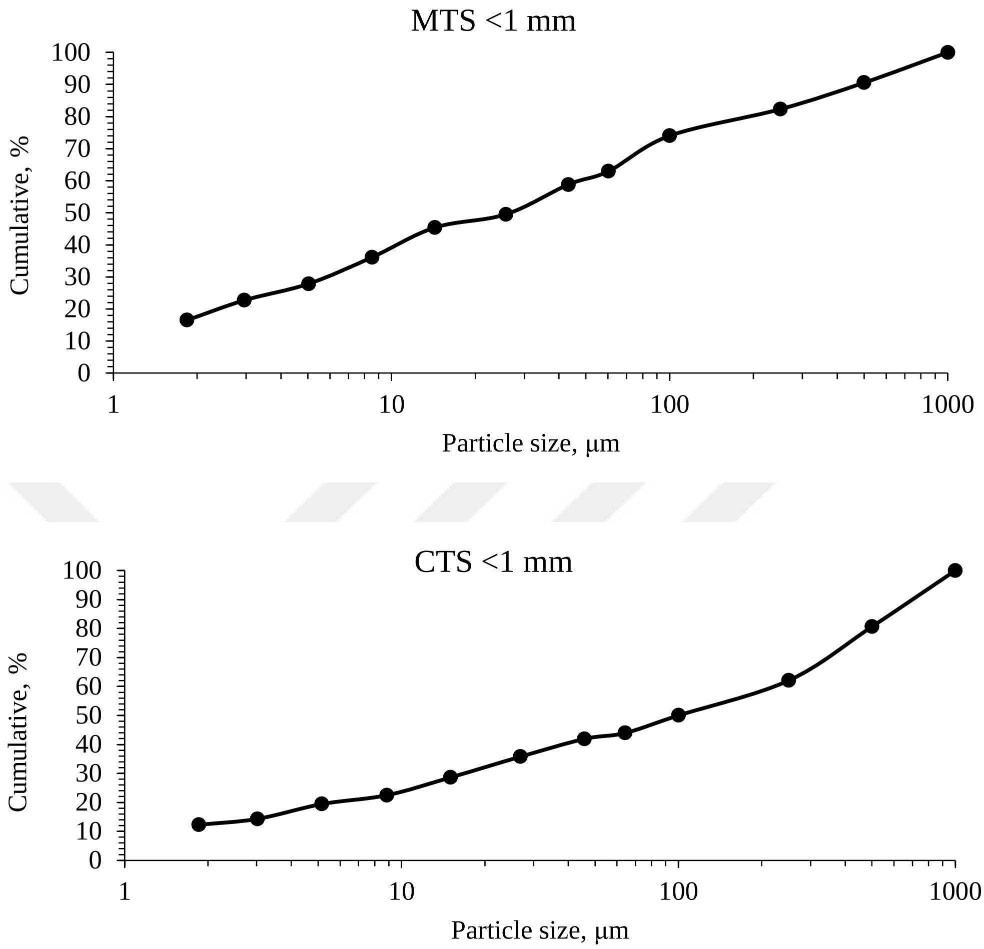


Figure 4.2.5. Particle size distribution for FTS, MTS and CTS <1 mm aggregate size

According to the particle size distribution curves results can be concluded that the clay percent of fine texture soil was more in compare to the medium and coarse texture soil. Also, the medium texture soil showed more clay percent in compare to the coarse texture soil. In addition this case, between the different aggregate sizes for three texture soil was shown the most clay percent for <1 mm aggregate size. The silt percent was more for the fine and medium texture soil in compare to the coarse texture soil but by decreasing aggregate size, the silt percent decreased for fine texture soil. Unlike the fine texture soil, by decreasing the aggregate size for the medium texture soil, the silt percent showed increasing. All of the texture well graded because all type of particles represented for the particle size distribution.

4.3. Soil Moisture Tension Curves

Soil moisture tension curves of coarse, medium and fine texture that belonged to the <4 mm, 4-2 mm, <2 mm, 2-1 mm and <1 mm aggregate sizes indicated at table 4.3.

Table 4.3. pF curve for different soils textures and aggregate sizes

Soil texture	Aggregate size, mm	Saturation, %	Field capacity, %	Permanent wilting point, %
FTS	<4	63,7	52,4	26,1
	4-2	65,1	56,4	21,9
	<2	58,1	49,8	19,1
	2-1	61,7	49,8	25,4
	<1	62,7	51,2	26,7
MTS	<4	46,9	26,3	12,8
	4-2	57,7	31,5	12,0
	<2	51,7	30,3	16,3
	2-1	55,8	27,0	12,4
	<1	56,1	29,4	19,7
CTS	<4	45,3	23,8	8,5
	4-2	42,9	14,0	9,3
	<2	48,9	23,7	11,7
	2-1	50,7	22,2	10,9
	<1	50,5	27,3	13,3

According to the table 4.3 the moisture percent under saturation condition increased from 45,3% to 46,9% and then to 63,7%, for the coarse, medium and fine texture soil respectively. This increasing was shown as 23,8% to 26,3% and then to 52,4% under the field capacity and 8,5% to 12,8% and then to 26,1% under permanent wilting point. Although by increasing the pF amount, the moisture percent decreased for the different texture soil, but this decreasing was more for the fine texture soil in compare to the two other textures. The fine texture soil had the most moisture percent and the coarse texture soil had the less moisture percent.

The moisture percent under saturation condition increased from 42,9 % to 57,7% and then to nearly 65,1%, for the coarse, medium and fine texture soil respectively. This increasing was shown as 14,0 % to 31,5% and then to 56,4% under the field capacity and 9,3% to 12,0% and then to 21,9% under permanent wilting point. Although by increasing the pF amount, the moisture percent decreased for the different texture soil, but this decreasing was more for the fine texture soil in compare to the two other textures. The fine texture soil had the most moisture percent and the coarse texture soil had the less moisture percent.

The moisture percent under saturation condition increased from 48,9% to 51,7% and then to 58,1%, for the Coarse, medium and fine texture soil respectively. This increasing was shown as 23,7% to 30,3% and then to 49,8% under the field capacity and 11,7% to 16,3% and then to 19,1% under permanent wilting point. Although by increasing the pF amount, the moisture percent decreased for the different texture soil, but this decreasing was more for the fine texture soil in compare to the two other textures. The fine texture soil had the most moisture percent and the coarse texture soil had the less moisture percent.

Moisture percent under saturation condition increased from 50,7% to 55,8% and then to 61,7%, for the coarse, medium and fine texture soil respectively. This increasing was shown as 22,2% to 27,0% and then to 49,8% under field capacity and 10,9% to 12,4% and then to 25,4% under permanent wilting point. Although by increasing the pF amount, the moisture percent decreased for the different texture soil, but this decreasing was more for the fine texture soil in compare to the two other textures. The fine texture soil had the most moisture percent and the coarse texture soil had the less moisture percent.

Moisture percent under saturation condition increased from 50,5% to 56,1% and then to 62,7%, for the coarse, medium and fine texture soil respectively. This increasing was shown as 27,3% to 29,4% and then to 51,2% under the field capacity and 13,3% to 19,7% and then to 26,7% under permanent wilting point. Although by increasing the pF amount, the moisture percent decreased for the different texture soil, but this decreasing was more for the fine texture soil in compare to the two other textures. The fine texture soil had the most moisture percent and the coarse texture soil had the less moisture percent.

As a result can be concluded that the fine texture soil keep more moisture in compare to the other textures and the coarse texture soil had the less moisture percent. Under various pF, this trend continued. But for the each texture soil different aggregate sizes did not show regular trend for the most and less moisture percent under different pF amounts.

4.4. Analytical Results

4.4.1. Aggregate Stability

The variance analysis results observed that aggregate stability showed the significant difference under all variance sources at 1% probability level except the interaction of soil and treatment and interaction of treatment and aggregate size that were non-significant. Also the mean comparison results indicated the most aggregate stability belonged to the medium and fine texture soil and the less aggregate stability related to the coarse texture soil under different soils. Mean comparison of the aggregate sizes effects on the aggregate stability showed the most value for the <1 mm aggregate size and the less for the 4-2 mm aggregate size. The PVA and control treatment mean comparison observed the significant difference and the most value for these results related to the PVA and the less value of aggregate stability was belonged to the control treatment. So, according to the results can be noted that with decreasing the aggregate size, aggregate stability increased and PVA caused to increase the aggregate stability, too (Table 4.4.1 - 4.4.4).

Table 4.4.1. Variance analysis on the studied properties of soil

Variation source	d.f	Aggregate stability, %	Hydraulic conductivity, cm/hr	ρ_b, g/cm^3	Dispersion ratio
Soil (S)	2	6856,1**	3259,156**	0,0896**	6889,23**
Aggregate size (AS)	4	359,7**	6,677**	0,0552**	1060,22**
Treatment(T)	1	68,5**	7,022**	0,1043**	13238,92**
S × AS	8	158,3**	0,244**	0,0170**	759,20**
S × T	2	5,8ns	0,863**	0,0050**	2930,73**
T × AS	4	5,7ns	0,133^{ns}	0,0058**	1239,51**
S × T × AS	8	30,3**	0,269**	0,0137**	421,53**
Exp. Error	60	3,1	0,069	0,0002	56,06

ns,*and ** non-significant, significant at 5 and 1 probability level, respectively.

Table 4.4.2. Mean comparison of evaluated properties for main effect of different soils

Soil treatment	Aggregate stability, %	Hydraulic conductivity, cm/hr	ρ_b, g/cm^3	Dispersion ratio
CTS	45,80 b	23,96 a	1,12 a	40,11 a
MTS	71,84 a	9,05 b	1,04 b	38,66 b
FTS	72,12 a	3,88 c	1,01 c	13,17 c

The means with non-similar letters in each column, have significant difference at 5% probability level.
CTS: coarse texture soil, MTS: medium texture soil, FTS: fine texture soil.

Table 4.4.3. Mean comparison of evaluated properties for main effect of different aggregate sizes

Aggregate size treatment	Aggregate stability, %	Hydraulic conductivity, cm/hr	ρ_b, g/cm^3	Dispersion ratio
<4mm	63,88 c	12,41 c	1,11 b	43,16 a
4-2mm	56,76 e	12,94 a	1,05 c	28,08 bc
<2mm	65,83 b	12,04 d	1,02 d	25,22 c
2-1mm	61,34 d	12,70 b	1,12 a	32,45 b
<1mm	68,46 a	11,39 e	1,01 e	24,34 c

The means with non-similar letters in each column, have significant difference at 5% probability level.
CTS: coarse texture soil, MTS: medium texture soil, FTS: fine texture soil.

Table 4.4.4. Mean comparison of evaluated properties for main effect of different treatments

	Aggregate stability, %	Hydraulic conductivity, cm/hr	ρ_b, g/cm^3	Dispersion ratio
Control	62,38 b	12,01 b	1,09 a	42,78 a
PVA	64,13 a	12,60 a	1,02 b	18,82 b

The means with non-similar letters in each column, have significant difference at 5% probability level.
CTS: coarse texture soil, MTS: medium texture soil, FTS: fine texture soil.

4.4.2. Hydraulic Conductivity

The variance analysis results indicated that hydraulic conductivity showed the significant difference under all variance sources at 1% probability level except the interaction of treatments and aggregate sizes that was non-significant. According to the mean comparison results there was significant different between the different soil and the most hydraulic conductivity belonged to the coarse texture soil and the less hydraulic conductivity related to the fine texture. Mean comparison of the aggregate sizes effects on the hydraulic conductivity showed the most value for the 4-2 mm aggregate size and the less for the <1 mm aggregate size. The PVA and control treatment mean comparison indicated the significant difference and the most value for these results related to the PVA and the less value of hydraulic conductivity was belonged to the control treatment. So, can be resulted that with decreasing the aggregate size, hydraulic conductivity decreased and PVA caused to increase the hydraulic conductivity, too (Table 4.4.1 - 4.4.4).

4.4.3. Bulk Density

According to the variance analysis results, bulk density showed the significant difference under all variance sources at 1% probability level. Also the mean comparison results indicated the most bulk density belonged to the coarse texture soil and the less bulk density related to the fine texture soil under different soils. Mean comparison of the aggregate sizes effects on the bulk density showed the most value for the 2-1 mm aggregate size and the less for the <1 mm aggregate size. The PVA and control treatment mean comparison observed the significant difference and the most value for these results related to the control and the less value of bulk density was belonged to the PVA treatment. So, according to the results can be discussed that by decreasing the aggregate size, bulk density decreased and PVA caused to reduce the bulk density, too. Because, PVA was sticked the aggregate together and produce more porosity and decrease the soil mass decreasing per one volume unit and reduce the bulk density (Table 4.4.1 - 4.4.4).

4.4.4. Dispersion Ratio

The variance analysis results indicated that dispersion ration showed the significant difference under all variance sources at 1% probability level. According to the mean comparison results there was significant different between the different soil and the most dispersion ratio belonged to the coarse texture soil and the less hydraulic conductivity related to the fine texture. Mean comparison of the aggregate sizes effects on the dispersion ratio showed the most value for the 4-2 mm aggregate size and the less for the <2 mm and <1 mm aggregate size. The PVA and control treatment mean comparison indicated the significant difference and the most value for these results related to the control and the less value of dispersion ratio was belonged to the PVA treatment. So, can be resulted that by decreasing the aggregate size, dispersion ratio decreased and PVA caused to decrease the dispersion ratio, too (Table 4.4.1 - 4.4.4).

4.5. Thermal Properties

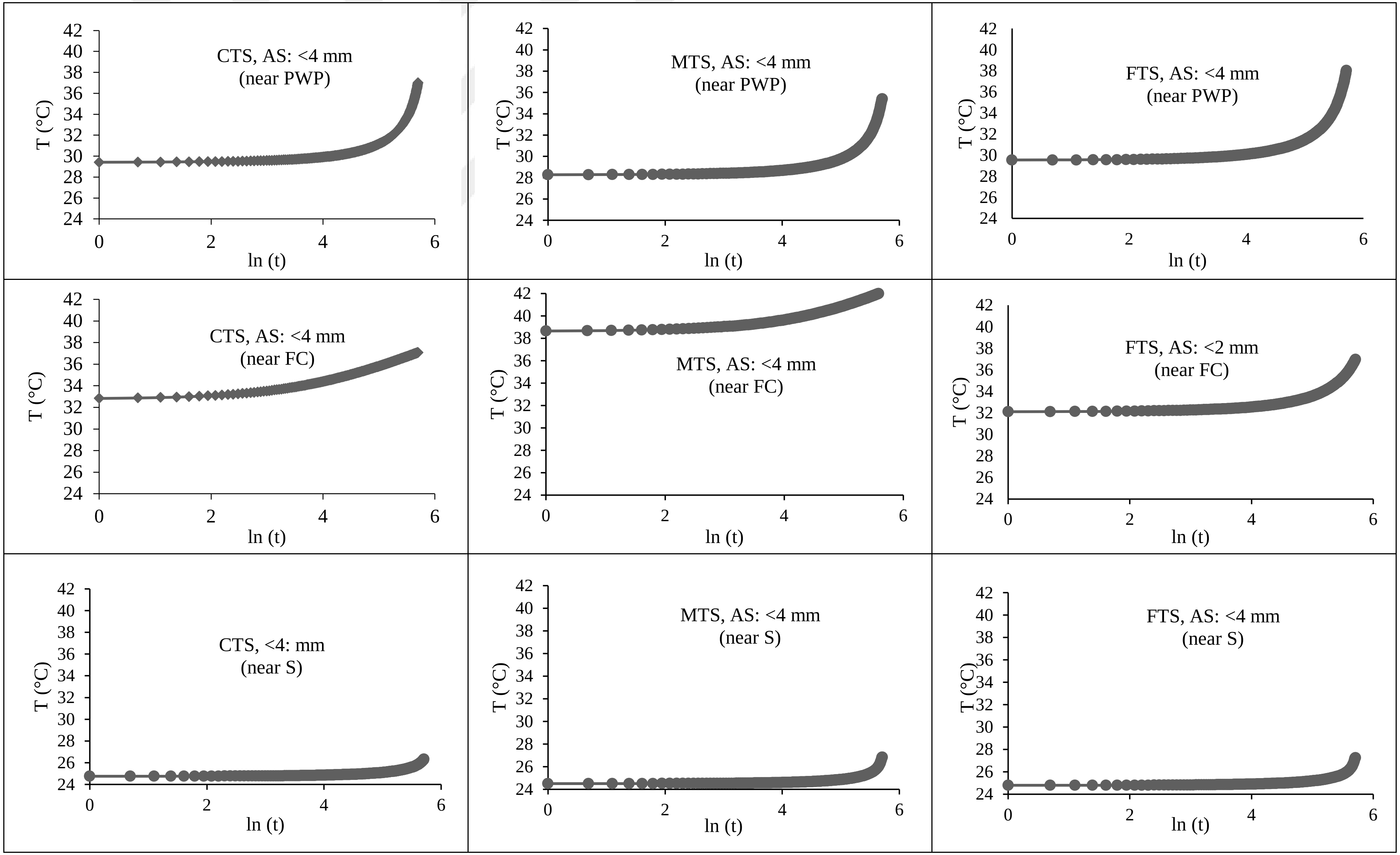
4.5.1. Heating phases curves to calculate thermal conductivity under different moisture condition

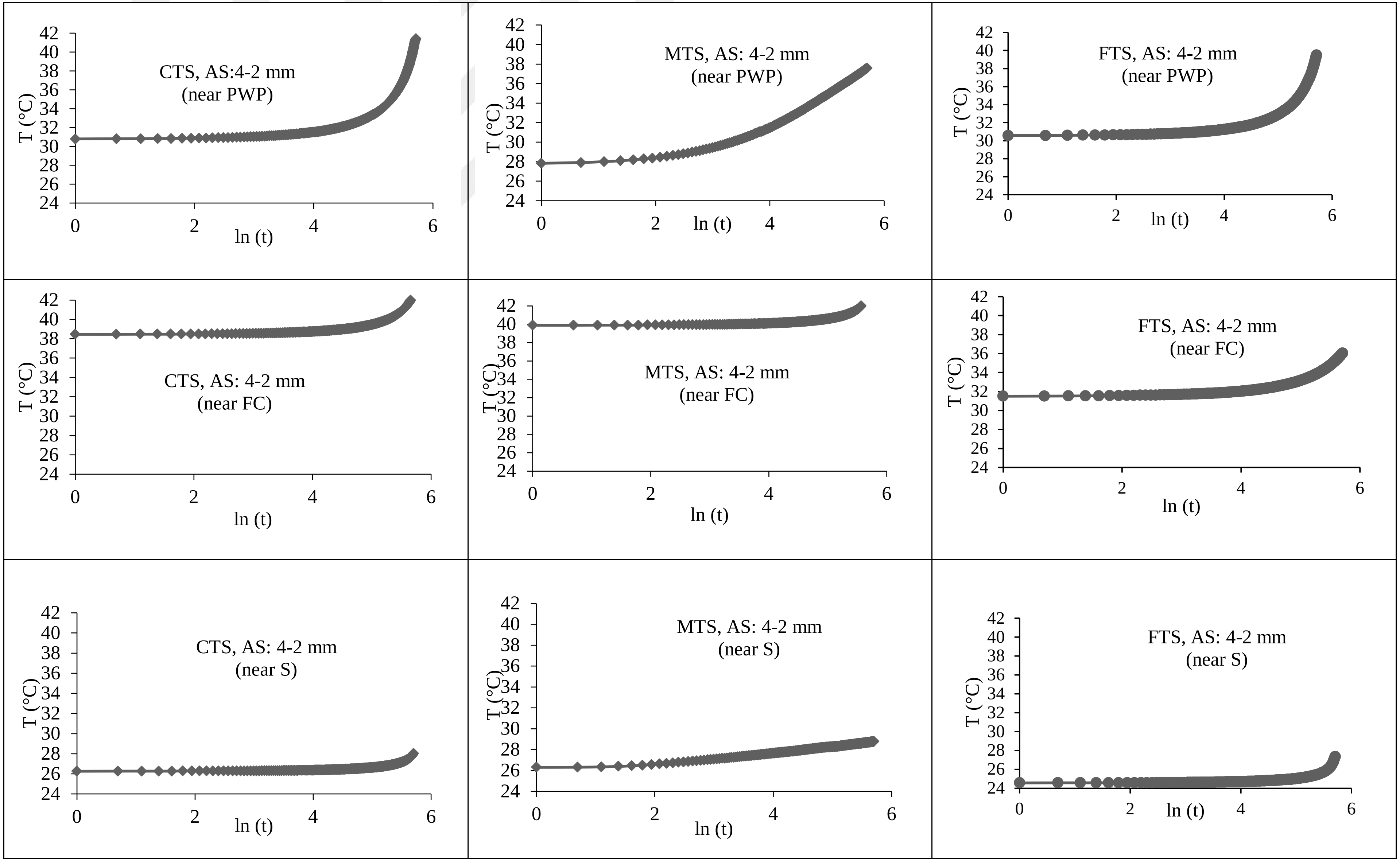
The measured thermal conductivity as experimental done by needle probe. These measuring were performed for the different aggregate sizes as <4 mm, 4-2 mm, <2 mm, 2-1 mm and <1 mm for the fine, medium and coarse texture soils under near saturation, near field capacity and permanent wilting point. The temperature changes during the measurement time used to drew the heating phase curves as Figures (4.51 - 4.5.5). By these data was calculated the thermal conductivity of soils samples.

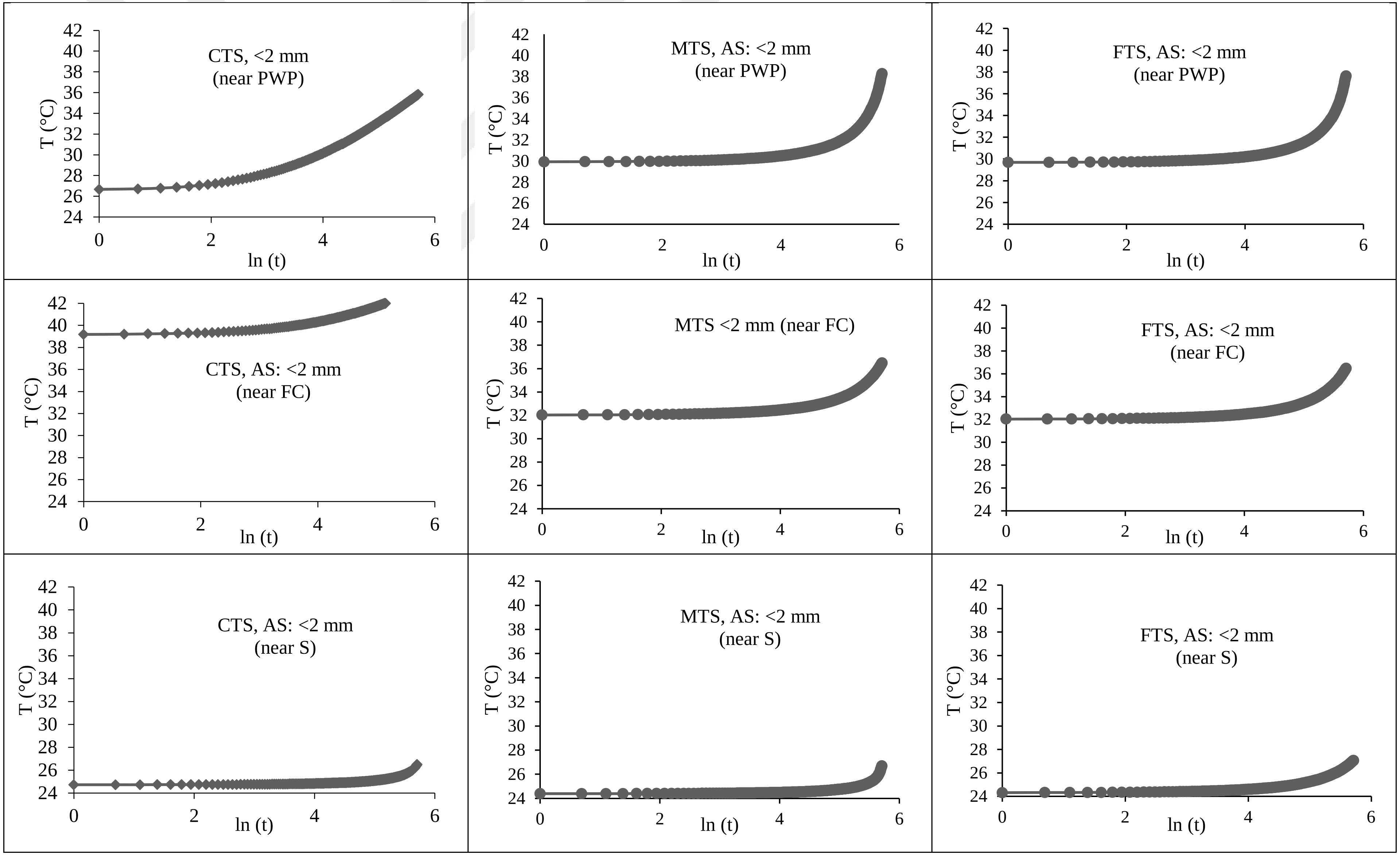
4.5.1.1. Heating phases curves of <4 mm aggregate size fraction

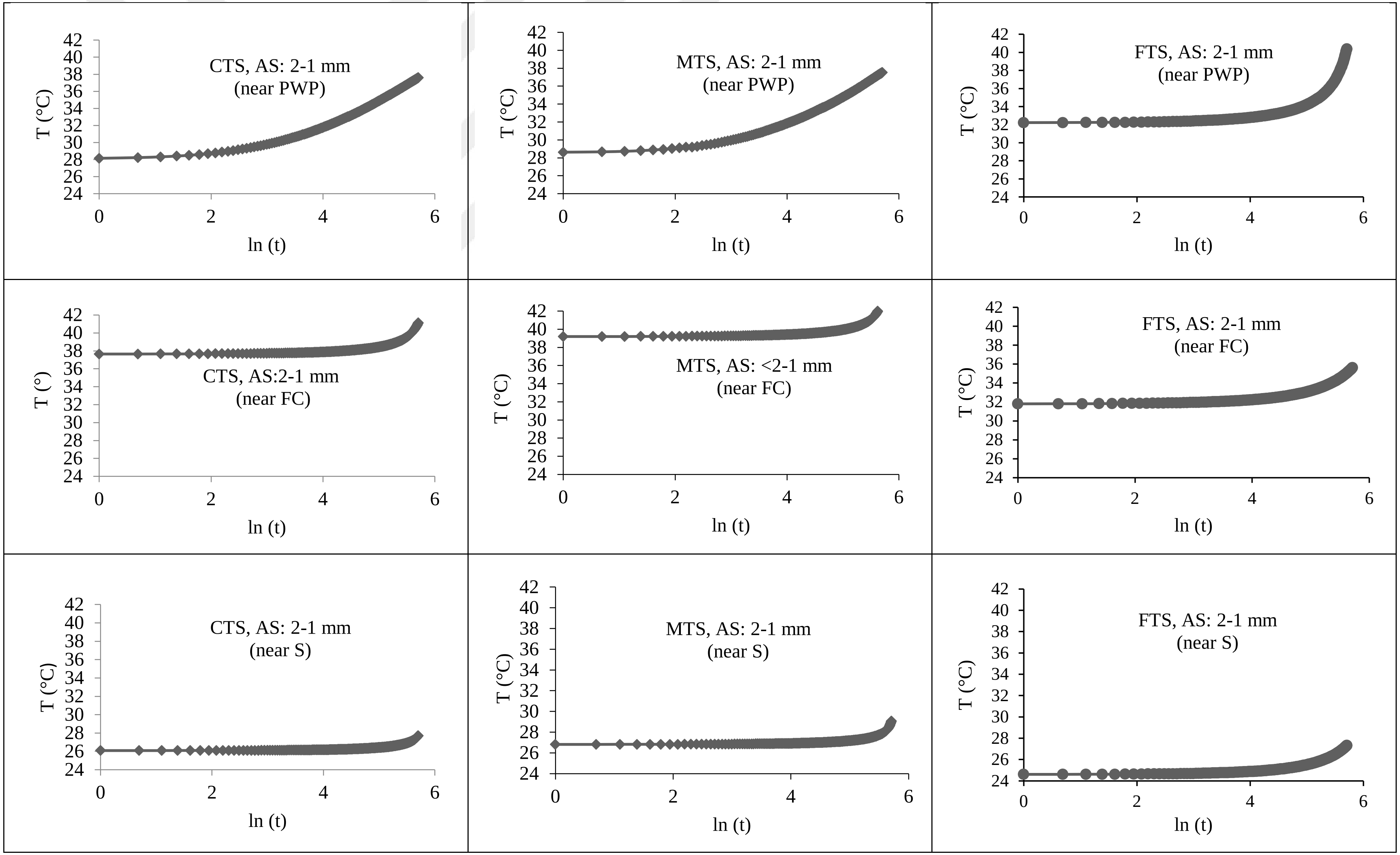
According to the Figure 4.5.1 results the temperature changes during the constant measurement time under the near saturation condition at medium texture soil was more than the other moisture content condition and at the coarse texture soil was low. Under near field capacity and permanent wilting point the fine texture and medium texture had the less temperature changes respectively and the most temperature changes showed at the medium texture and coarse texture soil, respectively. Also, under different moisture contents as near saturation, near field capacity and permanent wilting point conditions for the fine texture soil, the temperature changes was high under permanent wilting point and under the near field capacity condition was low. In addition for the medium texture soil under permanent wilting point had the less temperature changes and the high temperature changes were belonged to the near field capacity condition. The coarse texture soil showed the most temperature changes under the permanent wilting point, field capacity condition and the near saturation condition had the less temperature changes for the coarse texture soil.

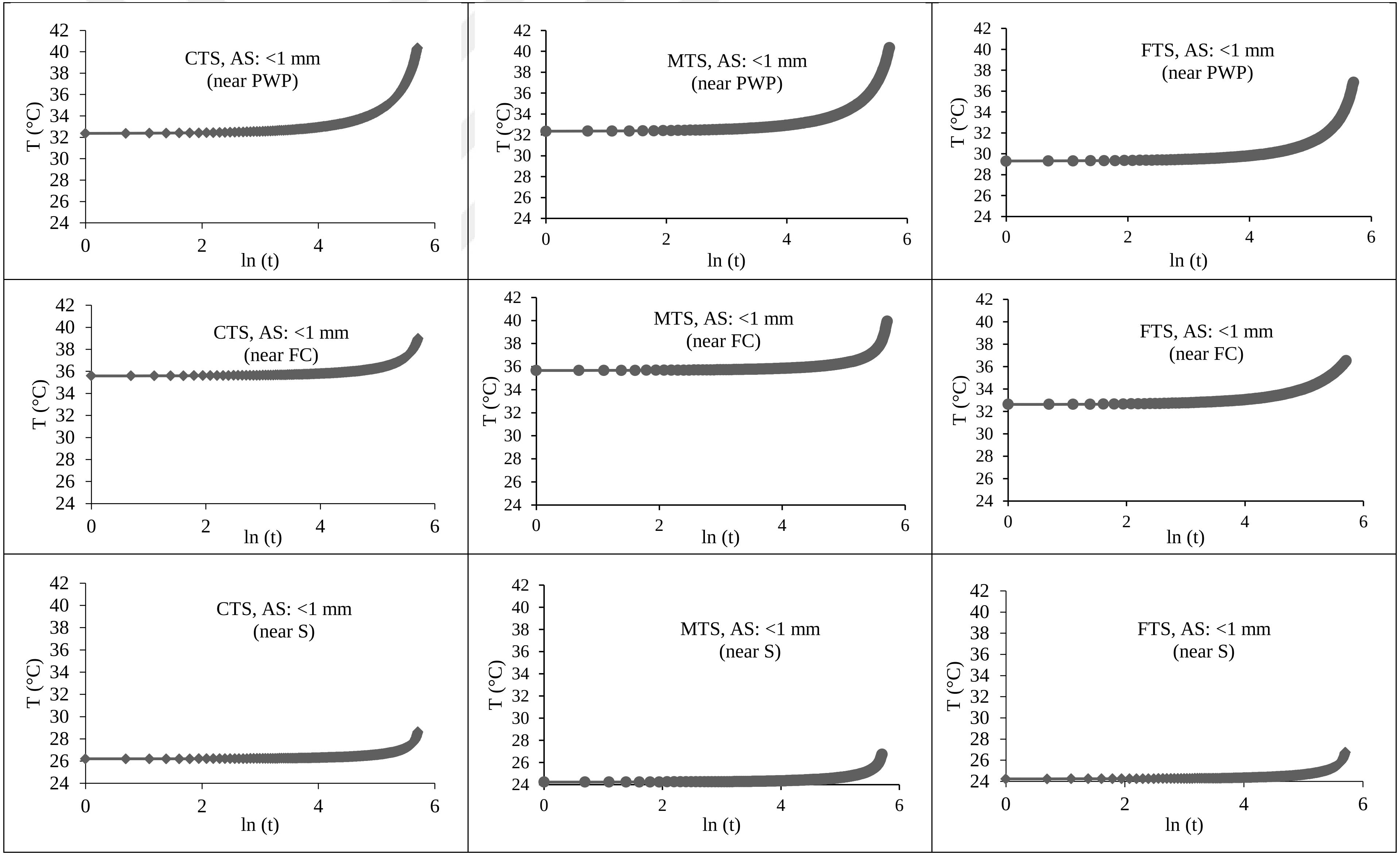
Figure 4.5.1-4.5.5. Heating phase curves of different soil textures with different aggregate size




CTS, AS:4-2 mm
(near PWP)
MTS, AS: 4-2 mm
(near PWP)
FTS, AS: 4-2 mm
(near PWP)
CTS, AS: 4-2 mm
(near FC)
MTS, AS: 4-2 mm
(near FC)
FTS, AS: 4-2 mm
(near FC)
CTS, AS: 4-2 mm
(near S)
MTS, AS: 4-2 mm
(near S)
FTS, AS: 4-2 mm
(near S)
T (°C)
ln (t)


CTS, <2 mm
(near PWP)
MTS, AS: <2 mm
(near PWP)
FTS, AS: <2 mm
(near PWP)
CTS, AS: <2 mm
(near FC)
MTS <2 mm (near FC)
FTS, AS: <2 mm
(near FC)
CTS, AS: <2 mm
(near S)
MTS, AS: <2 mm
(near S)
FTS, AS: <2 mm
(near S)
T (°C)
ln (t)
24 26 28 30 32 34 36 38 40 42
0 2 4 6


CTS, AS: 2-1 mm
(near PWP)
T (°C)
ln (t)
MTS, AS: 2-1 mm
(near PWP)
T (°C)
ln (t)
FTS, AS: 2-1 mm
(near PWP)
T (°C)
ln (t)
CTS, AS:2-1 mm
(near FC)
T (°)
ln (t)
MTS, AS: <2-1 mm
(near FC)
T (°C)
ln (t)
FTS, AS: 2-1 mm
(near FC)
T (°C)
ln (t)
CTS, AS: 2-1 mm
(near S)
T (°C)
ln (t)
MTS, AS: 2-1 mm
(near S)
T (°C)
ln (t)
FTS, AS: 2-1 mm
(near S)
T (°C)
ln (t)


CTS, AS: <1 mm
(near PWP)
MTS, AS: <1 mm
(near PWP)
FTS, AS: <1 mm
(near PWP)
CTS, AS: <1 mm
(near FC)
MTS, AS: <1 mm
(near FC)
FTS, AS: <1 mm
(near FC)
CTS, AS: <1 mm
(near S)
MTS, AS: <1 mm
(near S)
FTS, AS: <1 mm
(near S)
T (°C)
ln (t)
42
40
38
36
34
32
30
28
26
24
0
2
4
6

4.5.1.2. Heating phases curves of 4-2 mm aggregate size fraction

According to the Figure 4.5.2 results the temperature changes during the constant time under the near saturation condition at medium texture soil was high and at the fine texture soil was low. Also, under different moisture contents as near saturation, near field capacity and permanent wilting point condition for the fine texture soil, the temperature changes was high under near saturation condition in compare to the other moisture content and under the near saturation condition was low. In addition for the medium texture soil under permanent wilting point had the most temperature changes and the low temperature changes were belonged to the near field capacity. The coarse texture soil showed the most temperature changes under the permanent wilting point and the near saturation condition had the less temperature changes for the coarse texture soil.

4.5.1.3. Heating phases curves of <2 mm aggregate size fraction

According to the Figure 4.5.3 results the temperature changes during the constant measurement time under the near saturation condition at medium texture soil was more than the other moisture content condition and at the coarse texture soil was low. Under near field capacity and permanent wilting point the coarse texture and medium texture had the less temperature changes respectively and the most temperature changes showed at the fine texture and fine texture soil, respectively. Also, under different moisture contents as near saturation, near field capacity and permanent wilting point conditions for the fine texture soil, the temperature changes was high under near field capacity and under the permanent wilting point condition was low. In addition for the medium texture soil under permanent wilting point had the less temperature changes and the high temperature changes were belonged to the near field capacity condition. The coarse texture soil showed the most temperature changes under the permanent wilting point and near field capacity conditions and the near saturation condition had the less temperature changes for the coarse texture soil.

4.5.1.4. Heating phases curves of 2-1 mm aggregate size fraction

According to the Figure 4.5.4 results the temperature changes during the constant time under the near saturation condition at coarse texture soil was more than the other moisture content condition and at the medium texture soil was low. Also, under different moisture contents as near saturation, near field capacity and permanent wilting point conditions for the fine texture soil, the temperature changes was high under near field capacity condition and under the near saturation condition was low. In addition for the medium texture soil under permanent wilting point had the most temperature changes and the low temperature changes were belonged to the near saturation condition. The coarse texture soil showed the most temperature changes under the permanent wilting point and the near saturation condition had the less temperature changes for the coarse texture soil.

4.5.1.5. Heating phases curves of <1 mm aggregate size fraction

According to the Figure 4.5.5 results the temperature changes during the constant measurement time under the near saturation condition at medium texture soil was more than the other moisture content condition and at the fine texture soil was low. Under near field capacity and permanent wilting point the medium texture had the less temperature changes for both moisture condition and the most temperature changes showed at the fine texture and coarse texture soil, respectively. Also, under different moisture contents as near saturation, near field capacity and permanent wilting point conditions for the fine texture soil, the temperature changes was high under near field capacity and under the near saturation condition was low. In addition for the medium texture soil under near field capacity condition had the less temperature changes and the high temperature changes were belonged to near saturation condition. The coarse texture soil showed the most temperature changes under the permanent wilting point and field capacity condition and the near saturation condition had the less temperature changes for the coarse texture soil.

4.6. Measurement and Model Prediction Curves of Thermal Conductivity

According to the Figure 4.6.1 results, the most means value of thermal conductivity belonged to the de-Vries model and measurement data at the coarse soil texture. In comparison between the aggregate sizes, the most thermal conductivity related to the less than 1 mm in Kersten, Cote and Konrad, Tarnawski and measurement value and the less value of the thermal conductivity was for the 4-2 mm aggregate size under the named model and measurement value at the fine texture soil. Also, de-Vries model had the most thermal conductivity at less than 2 mm aggregate size and the less amount of thermal conductivity for this model belonged to the 4-2 mm aggregate size. Under all studied models and measurement value, the most thermal conductivity related to the near saturation condition and the less thermal conductivity was under the permanent wilting point at the fine texture soil.

Figure 4.6.2 results indicated that most mean value of thermal conductivity was reported as measurement value and the less mean value was predicted with Kersten model. Cote and Konrad model distinguished the most thermal conductivity as less than 4 mm aggregate size and the most amount of thermal conductivity was related to the 4-2 mm and 2-1 mm aggregate size for the medium soil texture. The less than 4 mm aggregate size showed the most value of thermal conductivity and 4-2 mm and 2-1 mm aggregate size had the less amount of thermal conductivity for the both Tarnawski and de-Vries model. The measurement value of thermal conductivity had two groups for the most and the less value of thermal conductivity that the most values belonged to the <4 mm and 2-1 mm as under PWP, respectively and the less value of thermal conductivity under near saturation condition related to the <2 mm and for the PWP, there was no significant difference between other aggregate size as the less value of thermal conductivity. Also, Thermal conductivity contained the most value under the near saturation condition and less value was under the permanent wilting point**.**

There was the most mean value of thermal conductivity for the measurement value and predicted value of de-Vries model for the coarse texture soil and the less mean amount of thermal conductivity belonged to the Kersten model at coarse texture soil (Fig 4.6.3). Kersten model had the less predicted value of thermal conductivity for the 4-2 mm aggregate size and the most value belonged to the <4 mm as Kersten predicted model. Cote and Konrad model predicted values were near together but can be noted that 2-1 mm aggregate size had the less and <1 mm aggregate size had the most value of thermal conductivity for this model. Tarnawski model showed the most thermal conductivity amount for 2-1 mm aggregate size and the less value belonged to the <4 mm aggregate size for this model. de-Vries predicted values of thermal conductivity had the most amount for the <1 mm and <4 mm aggregate size under PWP and near saturation condition, respectively. The thermal conductivity less value related to the 2-1 mm aggregate size and <1 mm aggregate size under P.W.P. and near saturation condition, respectively. Experimental measurement values showed the most amount for <1 mm aggregate size and the less amount for 2-1 mm aggregate size. Also, for all values, both prediction and measurement, thermal conductivity values was the most under near saturation condition and the permanent wilting point indicated the less amount of thermal conductivity at fine texture size.

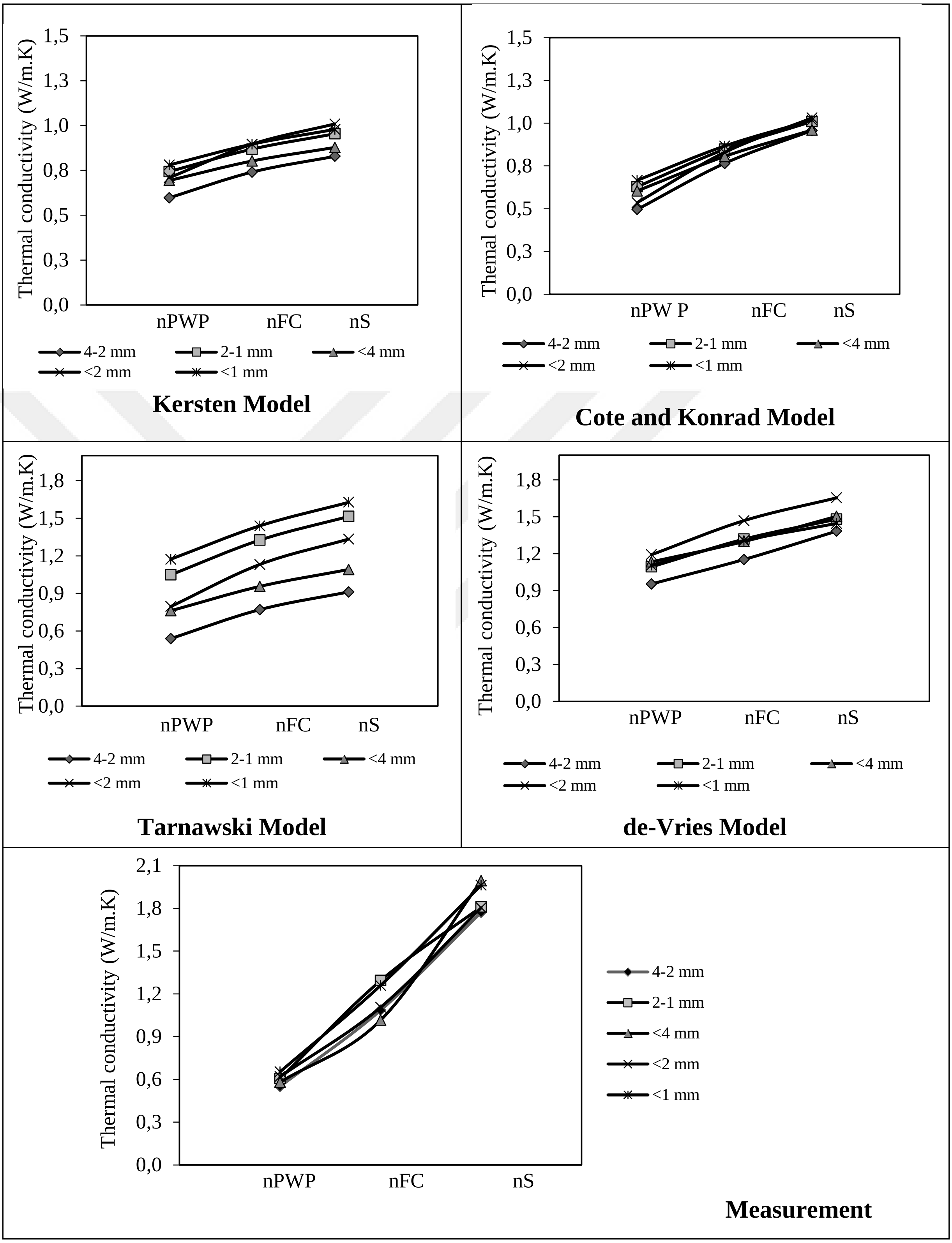


Figure 4.6.1. Thermal conductivity curves for FTS under different moisture condition as models prediction and experimental measurement

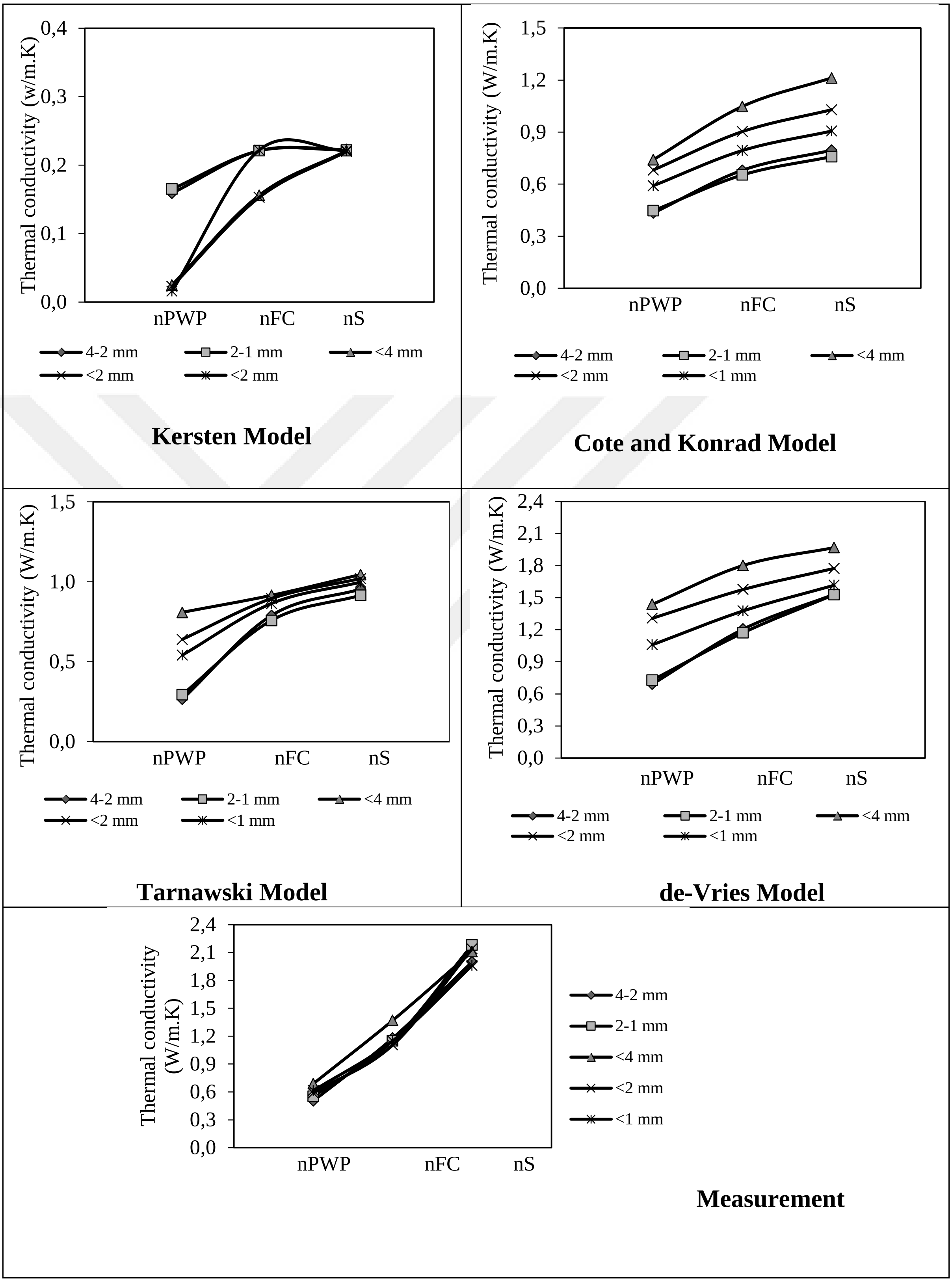


Figure 4.6.2. Thermal conductivity curves for MTS under different moisture condition as model prediction and experimental measurement

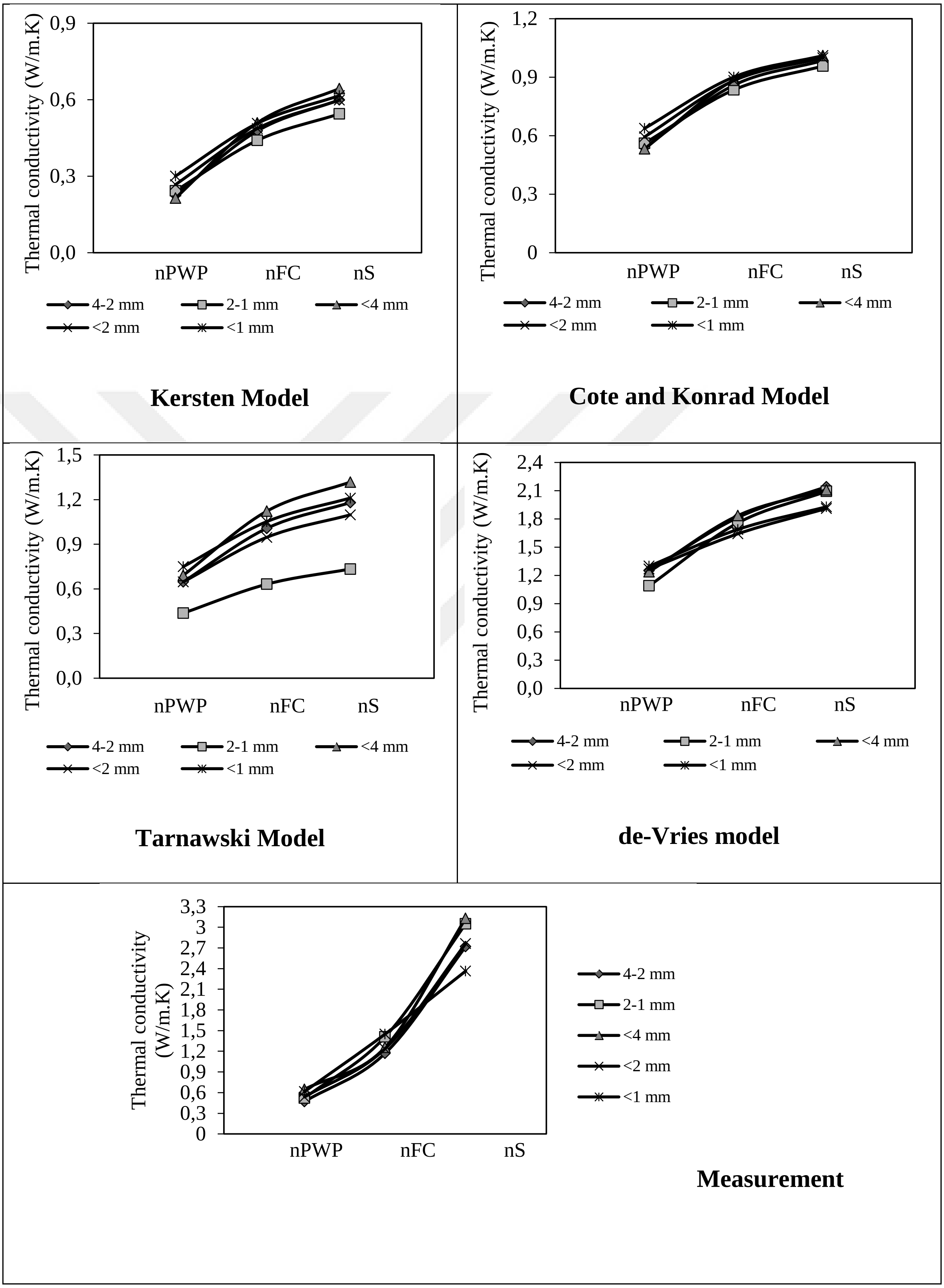


Figure 4.6.3. Thermal conductivity curves for CTS under different moisture condition as model prediction and experimental measurement

4.7. Measurement Values of Volumetric Heat Capacity

According to the table 4.7 results, the calculated volumetric heat capacity was similar for the models and measurement data as the results of bulk density and water content equality. But there were various volumetric heat capacity under the different water conditions and different soils that you can read the value as follow table. The volumetric heat capacity only used for calculating the thermal diffusivity value and did not compare between the different conditions.

Table 4.7. Measurement values of volumetric heat capacity

Volumetric heat capacity	4-2 mm			2-1 mm			<4 mm			<2 mm			<1 mm		
	Near Sat.	Near FC	Near PWP	Near Sat.	Near FC	Near PWP	Near Sat.	Near FC	Near PWP	Near Sat.	Near FC	Near PWP	Near Sat.	Near FC	Near PWP
FTS	3,1	2,3	1,6	3,3	2,6	1,9	3,1	2,5	1,9	3,3	2,5	1,7	3,3	2,7	2,1
MTS	3,0	2,1	1,2	2,7	1,9	1,2	3,5	2,6	1,6	3,4	2,5	1,6	3,3	2,4	1,5
CTS	3,0	2,2	1,3	2,8	2,1	1,4	3,2	2,3	1,3	3,2	2,3	1,4	3,3	2,4	1,5

4.8. Measurement and Model Prediction Curves of Thermal Diffusivity

Fine texture soil showed the less mean thermal diffusivity value for the experimental measurement value and the most mean of this observed for the cote and Konrad model (Fig 4.8.1). Kersten model had the less value of thermal diffusivity as <4 mm aggregate size and the most value belonged to the <2 mm aggregate size. The result for the cote and Konrad model was similar to the kersten model values. The most thermal diffusivity of the tarnawski model predicted value was for the <1 mm aggregate size and the less value belonged to the 4-2 mm aggregate size. de-Vries model value showed the most amount of thermal diffusivity for the less than 2 mm aggregate size and the less value related to the less than 1 mm aggregate size. Measurement data indicated the most and the less value for the <1 mm and 4-2 mm aggregate size, respectively.

Although, for the most amount of measurement data, there was no significant difference between the aggregate size but <1 mm aggregate size showed a little difference in compare to the other aggregate size. For the fine texture soil the near saturation condition contained the higher value of thermal diffusivity and permanent wilting point condition showed the less thermal diffusivity amount.

Figure 4.8.2. results showed the most mean value of thermal diffusivity as measurement value and the less amount of thermal diffusivity belonged to the cote and Konrad predicted value at medium texture soil. Kersten, tarnawski and de-Vries model had the similar less and most value of thermal diffusivity according to the aggregate size as the high value belonged to the <4 mm aggregate size and the less related to the 4-2 mm aggregate size. Cote and Konrad model value showed the high value for the 2-1 mm aggregate size and the less amount for <4 mm aggregate size. The measurement values were high for the 2-1 mm aggregate size and <2 mm aggregate size showed the less thermal diffusivity value as the measurement value. According to the difference, the near saturation condition had the high value of thermal diffusivity and the less value of thermal diffusivity belonged to the permanent wilting point.

The high mean value of thermal diffusivity of coarse texture soil was belonged to the measurement value and the less was shown for the kersten predicted value (Fig 4.8.3). Kersten model had the high value of thermal diffusivity for <1 mm and <4 mm aggregate size under P.W.P. and saturation condition, respectively and the less value for this model related to <4 mm and <1 mm aggregate size under P.W.P. and saturation condition too. The high value of thermal diffusivity under P.W.P. and saturation condition were as 2-1 mm aggregate size and <1 mm aggregate size for the cote and Konrad model. Also, this model had the less amount for <1 mm and <4 mm aggregate size under P.W.P. and saturation condition, respectively. Tarnawski showed the high value for 2-1 mm aggregate size and the less amount of thermal diffusivity for <4 mm aggregate size. Under PWP and near saturation condition, de-Vries model had the high value of thermal diffusivity for the 2-1 mm and 4-2 mm aggregate size, respectively. Also, The less amount of the thermal diffusivity as de-Vries predicted values belonged to the <1 mm and 2-1 mm aggregate size under PWP and near saturation condition, respectively. Under PWP condition the experimental measured values did show significant difference as the most and the less value for the aggregate sizes and under the near saturation condition the most value of thermal diffusivity was related to <4 mm aggregate size and <1 mm aggregate size had the less value for the measured value. Also, for the coarse textured soil, the near saturation condition had the high value of thermal diffusivity and the PWP showed the less value of thermal diffusivity, generally.

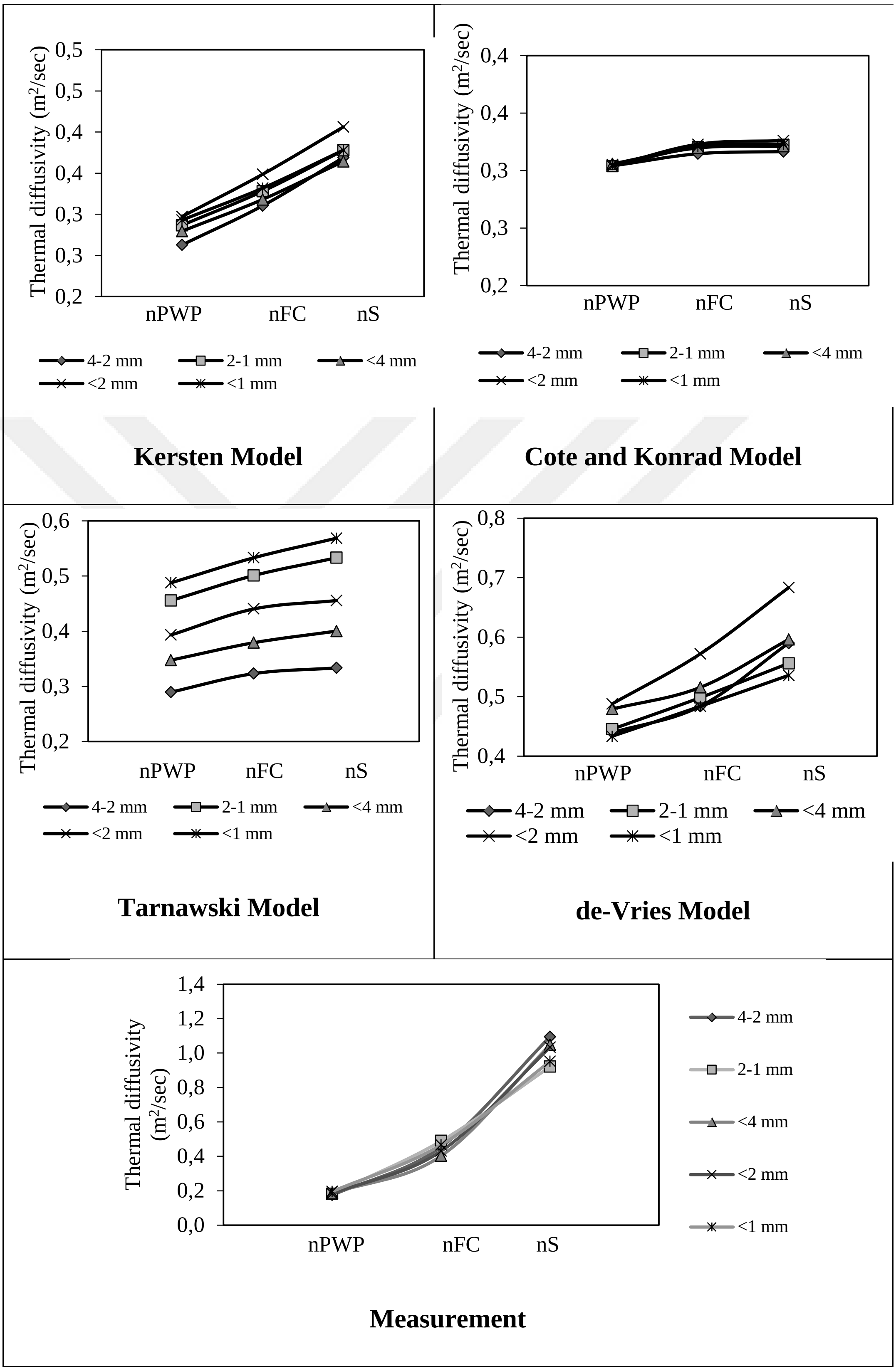


Figure 4.8.1. Thermal diffusivity curves for FTS under different moisture condition as model prediction and experimental measurement

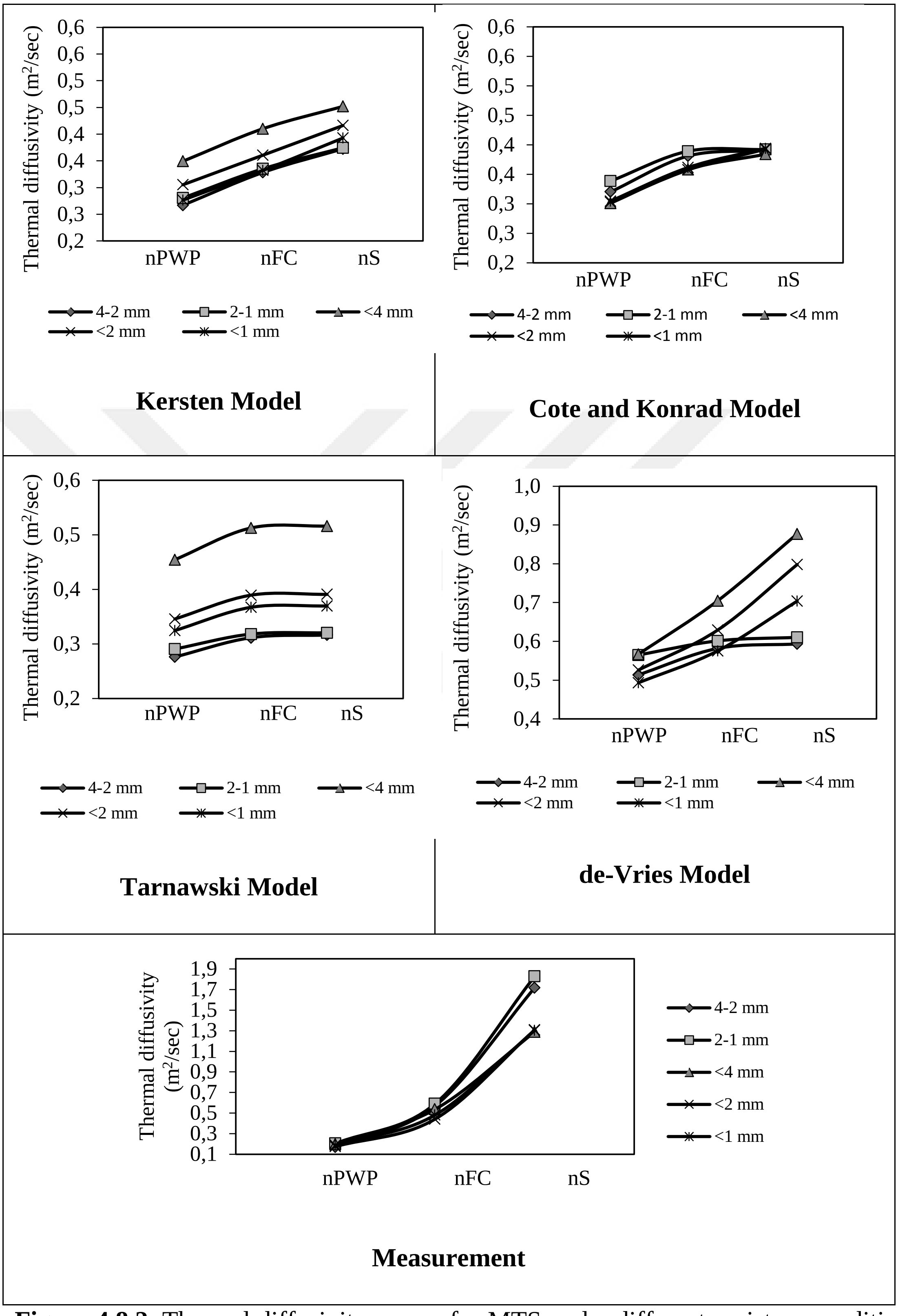


Figure 4.8.2. Thermal diffusivity curves for MTS under different moisture condition as model prediction and experimental measurement

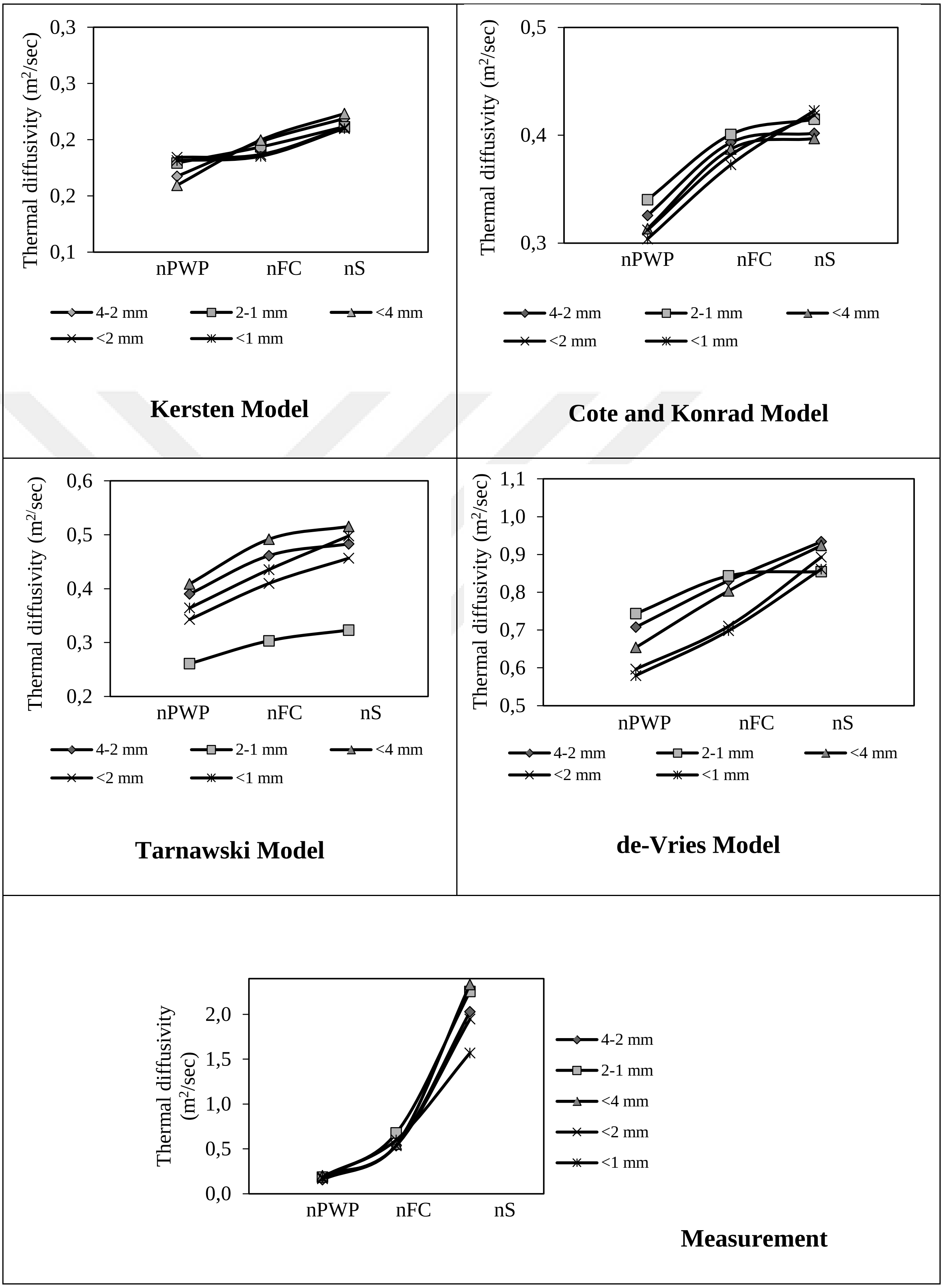


Figure 4.8.3. Thermal diffusivity curves for CTS under different moisture condition as model prediction and measurement

In this research resulted that de-Vries model had the thermal conductivity and thermal diffusivity values near to measurement values of two properties. Also, coarse soil texture had the most thermal properties (thermal conductivity and thermal diffusivity) and the fine texture soil values were the less, both for models and measurement values. By decreasing the aggregate sizes was shown decreasing for thermal conductivity values both for models and measurement values. Thermal properties of soil samples depended to the soil mineralogy, soil density, soil texture, soil water content and organic matter and changed by variation of these factors. This result of experiment was similar to the Dong et al. (2015) results that indicated soils thermal properties changes according to soil mineralogy, density, saturation state, and structure.

In this research was indicated that exact of models were different according to models factors and de-Vries model as theoretical model and Cote and Konrad model as empirical model had the predicted values near to measurement values. In addition to, as a result of the model factors difference, the predicted thermal properties values were different from a model to another. This results were similar to the Midttomme and Roaldset (1999) results that concluded most of the experimental results should be used in the calibration of these models on the base of transient methods. Such as Sakaguchi et al. (2007) results, was observed that coarse texture soil with high sand percent had the high thermal properties in compare to the fine texture soil with much clay percent.

Increasing the thermal properties resulted by the increasing the soil water content from permanent wilting point to near saturation condition for all of the studied models and measurement value and aggregate sizes. Similar to this research results, Tarnawski et al. (2000) and Hall and Allinson (2009) indicated the thermal properties values by raising the soil water content and they showed that thermal conductivity at first increases rapidly as the moisture content increases but beyond a certain moisture content, (approximately 3%), the rate of the increase become much lower.

By using of the factors that apply for the thermal properties measurement can be calibrated the model accuracy and exact. For example low porosity and high water content showed the most thermal properties as measurement. This result can be used to calibrate the model and model factors ratio. This result of experiment was similar to Alrtimi et al. (2016) results that observed the validation of some selected prediction models against the experimental results revealed. Variation of thermal properties according to soil water content from permanent wilting point to near saturation condition was another result of this research that was similar to Lu et al. (2007) results.

According to research results, Kersten model did not predict soil thermal properties under different water condition especially under saturation condition exactly. Zhang and Wang (2017) indicated result similar to this research result. Results showed that clay soil had the most volumetric heat capacity in compare to the other soil textures and this is similar to Abu-Hamdeh (2003) results. Among the soil factors, soil water content and soil texture were the effective factors on the thermal properties that had great effects on thermal properties especially on thermal conductivity. May and Shein indicated a result similar to this result, too.

For calculation thermal conductivity by using of de-Vries model quartz ratio and its relationship with water is important factor that can be influenced on soil thermal conductivity values. Usowicz et al. (2017) indicated that soil thermal conductivity was mainly governed by water content and quartz ratio of soil.

5. SUGESSTION

As the suggestion for this research can be noted:

Another researches can be evaluated the effect of soil components on the soil thermal conductivity and find the relationship between the details and soil thermal conductivity. Temperature changes can be measured continuously during some days and observed the variation during long time by thermal needle prob. Temperature changes can be measured by normal thermal sensors without heating phase under natural condition during some days and these measured values compare with the thermal needle probe temperature values. The temperature measurement values by thermal needle probe are done at different depth of soil profile and temperature changes is recorded according the depth, too. The relationship between thermal properties such as thermal conductivity, thermal diffusivity and volumetric heat capacity is evaluated as ratio under different water condition and different soil texture. Also, another research can be evaluated some chemical and organic material effects on the soil thermal properties and proposed the sufficient material to apply in the soil to keep the soil moisture under field capacity according to the soil temperature changes.

References

Abareshti, M., Goharshahi, E., Zebarjad, S.M., Fadafan, H.K. and Youssefi, A., 2010. Fabrication characterization and measurement of thermal conductivity of Fe_3O_4 nanofluids. J. Magn. Magn. Mater, 322, 3895-3901.

Abbasy, F., Hassani, F.P., Madiseh, S.A.G., Cote, J. and Nokken, M.R., 2014. An experimental study on the effective parameters of thermal conductivity of mine backfill. Heat transfer engineering. 35(13), 1209-1224.

Abu-Hamdeh, N.H., 2001. Measurement of the thermal conductivity of sandy loam clay loam soils using single and dual probes. J. Agric. Eng. Res. 80, 209-216.

Abu-Hamdeh, N.H., 2003. Thermal properties of soils as affected by density and water content. Biosys. Eng. 86(1), 97-102.

Abu-Hamdeh, N.H. and Reeder, R.C., 2000. Soil thermal conductivity: effects of density, moisture, salt concentration and organic matter. Sol Sci. Soc. Amer. J. 64, 1285-1290.

Abu-Hamdeh, N.H., Reeder, R.C., Khadir, A.I. and Al-Jalil, H.F., 2000. Thermal conductivity of disturbed soils under laboratory conditions. Transactions of the ASAE. 43(4), 855-860.

Abu-Hamdeh, N.H., Khadir, A.I. and Reeder, R.C., 2001. A comparison of two methods used to evaluate thermal conductivity for some soils. International Journal of Heat and Mass Transfer 44, 1073-1078.

Aggarwal, P., Mittal, R.B., Maity, P. and Sharma, A.R., 2009. Modification of Hydrothermal hydrothermal regimes under bed planted wheat. Geoderma 153, :312-317.

Alrtimi, A., Rouainia, M. and Haigh, S., 2016. Thermal conductivity of a sandy soil. Applied thermal engineering. 106, 551-560.

Anonymous, 2018. Turkish State Meteorological Service. Cities & Holiday Resorts. https://mgm.gov.tr/eng/forecast-cities.aspx?m=ERZURUM 10.03.2018.

Arkhangelskaya, T. and Lukyashchenko, K., 2017. Estimating soil thermal diffusivity at different water contents from easily available data on soil texture, bulk density, and organic carbon content. Biosystems engineering p. 1-13.

Arriaga, J., Rubio, F.R. 2017. A distributed parameters model for soil water content: Spatial andtemporal variability analysis. Agricultural Water Management, 183, 101-106.

ASTM D 5334, 2008. A testing method for determining the thermal conductivity of soil and soft rocks by a thermal needle probe procedure,.

ASTM E 518, 2009. Standard test method for steady-state thermal transmission properties by means of the heat flow meter apparatus.

ASTM D 5334, 2014. Standard test method for determination of thermal conductivity of soil and soft rock by thermal needle probe procedure.

ASTM D2937, 2010. Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method.

Bachmann, J., 1997. Thermisches verhalten der Böden. In: Blume, H.P., Felix Henningsen, W. R. Fisher, H.-G. Frede, R. Horn and K.Stahr (Hrsg.): Handbuch der Bodenkunde, 2, Ecomed, Landsberg, Lech, p. 1-40.

Balland, V. and Arp, P.A., 2005. Modeling soil thermal conductivities over a w idde range of conditions. J. Environ. Eng. Sci. 4(6), 549-558.

Barik, K., 1998. Toprakların Isısal Özelliklerinin Matematik Model ile Belirlenmesi. Atatürk Üni. Fen Bilimleri Enstitüsü Yüksek Lisans Tezi,, Toprak Bilimi Anabilim Dalı Erzurum.

Blake, G.R. and Hartge, K.H., 1986a. Bulk density. In: Klute, A., (ed.) Methods of soil analysis: Physical and mineralogical methods. Madison, American Society of Agronomy. p. 363-376.

Bockheim, J., Vieira, G., Ramos, M., Lopez-Martinez, J., Serrano, E., Guglielmin, M., Wilhelm, K. and Nieuwendam, A., 2013. Climate warming and permafrost dynamics in the Antarctic Peninsula region. Glob. Planet. Chang. 100, 215-223.

Bozdag, S. and Paksoy, H., 2008. Ground water level influence on thermal response test in Adana, Turkey. Int. J. Energy Res. 32, 629-633.

Bremner, J.M. and Mulvaney, C.S., 1982. NitrogenĐtotal. In: Page, A.L., Miller, R.H., Keeney, D.K. (Eds.). Methods of Soil Analysis. Part 2DChemical and Microbiological Properties. Soil Science of America, Inc, Wisconsin, p. 595-616.

Bristow, K.L., Kluitenberg, G.J., Goding, C.J. and Fitzgerald, T.S., 2001. A small multi-needle probe for measuring soil thermal properties, water content and electrical conductivity. Computers and Electronics in Agriculture, p. 265-280.

Bryan, R.B., 1968. The development, use and efficiency of indices of soil erodibility. Geoderma. 2, 5-25.

Campbell G.S.,1985. Soil Physics with Basic; Transport Models for Soil-Plant Systems. Elsevier, New York.

Campbell G.S., Jungbauer J.D., Bidlake W.R. and Hungerford R.D., 1994. Predicting the effect of the temperature on soil thermal conductivity. Soil Science, 158, 307–313.

Campbell, G.S. and Norman, J.M., 1998. An introduction to environmental biophysics. Springer Verlag, New York.

Canbolat, M.Y. ve Barik, K., 1998. Pedotransfer fonksiyonları ile tahmin edilen toprak nem ve ısı karakteristiklerinin değerlendirilmesi. M. Şefik YEŞİLSOY International Symposium on Arid Region Soils, p: 350-355. International Agrohydrology Research and Training Center, Menemen-İzmir, TURKEY.

Carminati, A., Kaestner, A., Lehman, P. and Fluhler, H., 2008. Unsaturated water flow across soil aggregate contacts. Adv. Water Res. 31, 1221-1232.

Carslaw, H.S. and Jaeger, J.C., 1959. Conduction of heat in solids. 2nd ed. Oxford: Oxford University Press.

Cassel, D.K. and Sweeney, M.D., 1974. In situ soil water holding capacities of selected North Dakota soils. North Dakota Agric. Exp. Stn. Bull. 495.

Cebron, A., Beguiristain, T., Faure, P., Norini, M.P., Masfaraud, J.F. and Leyval, C., 2009. Influence of vegetation on the in situ bacterial community and polycyclic aromatic hydrocarbon (PAH) degrades in aged PAH-contaminated or thermal-desorption-treated soil. Appl. Environ. Microbiol. 75, 6322-6330.

Cebron, A., Cortet, J., Criquent, S., Biaz, A., Calvert, V., Caupert, C., Pernin, C. and Leyval, C., 2011. Biological functioning of PAH-Polluted and thermal-desorption treated soils assessed by fauna and microbial bioindicators. Res. Microbial. 162, 896-907.

Chen, S.X., 2008. Thermal conductivity of sands. Heat Mass Transf. 44(10), 1241-1246.

Chen, Z.S. and Qian, J., 1992. Predicting theory of effective thermal conductivity of complex material. China science and technology university journal. 22(4), 416-424.

Certini, G., 2005. Effects of fire on properties of forest soils: a review. Oecologia. 143, 1-10.

Chacko, T.P. and Renuka, G., 2002. Temperature mapping, thermal diffusivity and subsoil heat flux at Kariavattom of Kerala, Proc. Indian Acad. Sci. (Earth Planetary. Science), 111(1), 79-85.

Chang, G. Q., 2011. Ground thermal properties test and analysis for ground source heat and pump. Chongqing University (in Chinese).

Choi, J., Lee, S. and Lee, D., 2011. Numercial simulation of vertical ground heat exchangers: intermittent operation in unsaturated soil conditions. Comput Geotechn. 38(8), 949-958.

Ciocca, F., Lunati, I., Van de Giesen, N. and Parlang, M.B., 2012. Heated optical fiber for disturbed soil-moisture measurement: a lysimeter experiment. Vadose zone journal. 11(4), 1-10.

Clarke, B.G., Agab, A. and Nicholson, D., 2008. Model sspecification to determine thermal conductivity of soils. Proc. Inst. Civil Eng.: Geotech. Eng. 161(3), 151-168.

Cote J. and Konrad J.M., 2005. A generalized thermal conductivity model for soils and construction materials. Canadian Geotechnical Journal, 42: 443–458.

Damfeu, J.C., Meukam, P. and Jannot, Y., 2016. Modeling and estimation of the thermal properties of clusters aggregates for construction materials: The case of clusters aggregates of lateritic soil, sand and pouzzolan. International journal of heat and mass transfer. 102, 407-416.

Day, P.R., 1965. Particle fractionation and particle-size analysis. P. 545-567. In C.A. Black et al. (ed.) Methods of soil analysis, Part I. Agronomy. 9, 545-567.

de Vries, D.A., 1963. Thermal properties of soils. In: Van Wijk WR, editor. Physics of the plant environment. New York: John Wiley and Sons; p. 210-235.

Dec, D., Dorner, J. and Horn, R., 2009. Effect of soil management on their thermal properties. J. Soil Sci. Plant Nutr. 9(1), 26-39.

Demiralay, İ., 1993. Toprak fiziksel analizleri. Atatürk Üniversitesi Ziraat Fakültesi Yayınları, 143, 13-19.

Dissanayaka, Sh.H., Hamamoto, Sh., Komatsu, T., 2013. Thermal properties for peaty soil under variable saturation and their correlation to mass transport parameters in gaseous and aqueous phases. Research report of department of civil and environmental engineering, Saitama Uni. Vol, 39.

Donazzi, F., Occhini, E. and Seppi, A. 1979. Soil thermal and hydrological characteristics in designing underground cables, Proc. IEE. 126(6), 506-516.

Dong, Y., Mc Cartney, J.S. and Lu, N., 2015. Critical review of thermal conductivity models for unsaturated soils. Geotech. Geol. Eng. 33(2), 207-221.

Dowdy, S. and Wearden, S., 1983. Statistics for Research. John Wiley and Sons, Inc. USA.

EKBERLİ, İ. Ve SARILAR, Y., 2015. Toprak Sıcaklığının Profil Boyunca Sönme Derinliğinin ve Gecikme Zamanının Belirlenmesi Ege Üniv. Ziraat Fak. Derg. 52 (2), 219-225 ISSN 1018 – 8851.

Ekberli, İ., Gülser, C. ve Mamedov, A., 2015.Toprakta bir boyutlu ısı iletkenlik denkleminin incelenmesinde benzerlik teorisinin uygulanması. Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi. 10(2), 69-79.

Ekberli, İ., Gülser, C. ve Özdemir, N., 2005. Toprakların termo-fiziksel özellikleri ve ısısal yayınım katsayısının değerlendirilmesi. OMÜ Zir. Fak. Dergisi. 20(2), 85-91.

Ekberli, İ., Gülser, C. ve Özdemir, N., 2017. Farklı toprak derinliklerindeki sıcaklığın tahmininde parabolik fonksiyonun kullanımı. Toprak Bilimi ve Bitki Besleme Dergisi. 5 (1), 34- 38.

Evett, R.S., Agam, N., Kustas, W.P., Colaizzi, P.D. and Schwartz, R.C., 2012. Soil profile method for soil thermal diffusivity, conductivity and heat flux: Comparison to soil heat flux plates. Adv. Water Res. 50, 41-54.

Fan, R., Jiang, Y. and Yao, Y., 2007. A study on the performance of a geothermal heat exchanger under coupled heat conduction and groundwater advection. Energy. 32, 2199-2209.

Farouki, O.T., 1981. Thermal Properties of Soils. Cold region research and engineering laboratory (CRREL) monograph, 81(1), 137.

Farouki, O.T., 1986. Thermal properties of soil, series on rock and soil mechanics, trans. Tech. Publications, Germany.

Galang, M.A., Markewitz, D., Morris, L.A., 2010. Soil phosphourus transformations under forest burning and laboratory heat treatments. Geoderma. 155: 401-408.

Gangadhara Rao, M.V.B.B. and Singh, D.N., 1999. A generalized relationship to estimate thermal resistivity of soils. Can. Geotech. J. 36(4), 767-773.

Gawin, D., Schrefler, B.A. and Galindo, M., 1996. Thermo-hydro-mechanical analysis of partially saturated porous materials. Eng Comput. 13(7), 113-43.

Gee, G.W. and Bauder, J.W., 1986. Particle-size analysis. pp. 383-409. In Klute, A. (ed.). Methods of soil analysis. Part 1. Physical and mineralogical methods. 2nd ed. Agron. Monogr. 9. ASA AND SSSA, Madison, WI.

Ghuman, B.S. and Lal, R., 1985. Thermal conductivity, thermal diffusivity and thermal capacity of some Nigerian soils. Soil Sci. 139, 74-80.

Glass, D.W., Johnson, D.W., Blank, R.R. and Miller, W.W., 2008. Factors effecting mineral nitrogen transformations by soil heating: a laboratory-simulated fire study. Soil Sci. 173, 387-400.

Goodrich, L.E., 1986. Field measurement of soil thermal conductivity. Can. Geotech. J. 23, 51-59.

Gori, F., 1983. A theoretical model for predicting the effective thermal conductivity of unsaturated frozen soils. In: Proc 4th Int conf on permafrost Fairbanks, p. 363-368.

Gori, F. and Corasaniti, S., 2002. Theoretical prediction of the soil thermal conductivity at moderately high temperatures. J. Heat Transf. 124(6), 1001-1008.

Gray, D.M. and Dighton, J., 2006. Mineralisation of forest litter nutrient by heat and combustion. Soil Biol. Biochem. 38, 1469-1477.

Haigh, S.K., 2012. Thermal conductivity of sands, Geotechnique. 62 (7), 617-625.

Hall, M. and Allinson, D., 2009. Assessing the effects of soil grading on the moisture content-dependent thermal conductivity of stabilised rammed earth materials, Appl. Therm. Eng. 29 (4), 740–747.

Hamuda, S., 2009. The relation between soil composition and its thermal characteristics (Ph.D thesis). Newcastle University, UK.

Hansen, S., Jensen, H.E., Nielsen, N.E. and Svendsen, H., 1990. NPO-research, A10: Daisy: Soil plant atmosphere system model. The national Agency of Environmental protection, Copenhagen.

Haung, F., Zhan, W., Ju, W. and Wang, Z., 2014. Improved reconstruction of soil thermal field using two-depth measurements of soil temperature. Journal of Hydrology. 519, 711-719.

Hillel, D., 1982. Introduction to Soil Physics. Academic Press, San Diego, CA.

Hillel, D., 1998. Environmental Soil Physics. Academic Press, London, 771 P.

Hiraiwa, Y. and Kasubuchi, T., 2000. Temperature dependence of thermal conductivity of soil over a wide range of temperature. Eur. J. Soil Sci. 51, 211-218.

Horn, R. and Smucker, A., 2005. Structure formation and its consequences for gas and water transport in unsaturated arable and forest soils. Soil Till. Res. 82: 5-14.

Horton, R., 2002. Soil thermal diffusivity. Methods soil Anal.: 4 Phys. Methods, 1227-1232 (ASA-CSSA-SSSA).

Horton, R. Wierenga P. J. and Nielsen D. R., 1983. Evaluation of methods for determining the apparent thermal diffusivity of soil near the surface. Soil Sci. Soc. of Amer. J. 47(1), 25-32.

Hu, L., 2009. The soil thermal properties test and analysis of various factors that affect underground temperature distribution in ground source heat pump system. Huazhong University of science and technology (in Chinese).

Hu, X.J., Du, J.H. and Wang, B.X., 2001. The influence of liquid saturation on the stagnant thermal conductivity of porous media. Journal of engineering thermophysics. 22: 125-128.

IPCC, 2014. Climate change 2014. In: Team, C.W., Pachauri, R.K., Meyer, L.A. (Eds.), Synthesis report. Contribution of working groups I, II and III to fifth Assessment report of the intergovermental panel on climate change. IPCC, Geneva, Switzerland.

Jackson, R.D. and Taylor, S.A., 1965. Heat transfer, in: C.A. Black et al. (Eds.), Methods of soil analysis: Part 1, Agron Monograph, 9, ASA, Madison, WI. Pp: 349-356.

Jiao, A.J., Li, Y.Z. and Zhang, R., 2001. The study of the adiabatic performance of the dilated perlite in the heat transfer under steady or unsteady state. Cryogenics. 2, 48-52.

Johansen, O., 1975. Thermal conductivity of soils. Ph.D. thesis. Trondheim, Norway: University of Trondheim; Us Army crops of engineers, Cold Regions research and engineering laboratory, Hanover, N.H. CRREL Draft english translation 637.

Ju, Z.Q., Ren, T.S. and Hu, C.S., 2010. Soil thermal conductivity as influenced by aggregation at intermediate water contents. Soil Sci. Soc. Amer. J. 75, 26-29.

Kang, B.T. and Sajjapongse, A., 1980. Effect of heating on properties of some soils from southern Nigeria and growth of rice. Plant Soil. 55, 85-95.

Kara, M., Ozturk, I., Bastaban, S. and Kalkan, F., 2011. Thermal conductivity of safflower (Carthamus tinctorius L.) seeds. Spanish Journal of Agriculture Research. 9(3): 687-692.

Kemper, W.D. and Koch, E.J., 1966. Aggregate stability of soils from the western portions of the United states and Canada. USDA Tech. Bull. 1355. U.S. Gov. Print. Office, Washington, DC.

Kemper, W.D. and Rosenau, R.C., 1986. Aggregate stability and size distribution. P. 425-442. In A. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed. ASA and SSSA madison, WI.

Kersten, M.S., 1949. Laboratory research for the determination of the thermal properties of soils. Bulletin (No. 28. Minneapolis, MN: University of Minnesota Engineering experiment station).

Ketterings, Q.M., Bigham, J.M. and Laperche, V., 2000. Changes in soil mineralogy and texture caused by slash and burn fires in Sumatra, Indonesia. Soil Sci. Soc. Amer. J. 64, 1108-1117.

Kim, D.H., Kim, G.M., Park, S.H. and Baek, H.J., 2013. Changes in the thermal conductivity of bentonite-based grouts with varying volumetric water content, Geosyst. Eng. 16 (4): 257-264.

Klute, A. and Dirksen, C., 1986. Hydraulic Conductivity and Diffusivity: Laboratory Methods, in A. Klute (editor), Methods of Soil Analysis, Part 1: Physical and Mineralogical Methods, 2nd ed., pp. 687–734, American Society of Agronomy, Inc., and Soil Science Society of America, Madison, WI.

Kodide, U., 2010. Thermal conductivity and its effects on the performace of PCC pavements in MEPDG. A thesis of the Louisiana State University and Agricultural and Ingersoll, I., Plass, H. 1948. Theory of the ground pipe heat source for the heat pump, ASHRAE Trans. 54(7), 339-348.

Kohout, M., Collier, A.P. and Stepanek, F., 2004. Effective thermal conductivity of wet particle assemblies, Int. J. Heat Mass Transfer. 47 (25), 5565-5574.

Kramer, P.J. and Boyer, J.S., 1995. Water Relations of Plants and Soils. Academic Press, Inc. 495 P.

Kustas, W.P., Prueger, J.H., Hatfield, J.L., Ramalingam, K. and Hipps, L.E., 2000. Variability in soil heat flux from a mesquite dune site. Agric. Forest Meteorol. 103, 249-264.

Lee. C.K., and Lam, H.N., 2012. A modified multi-ground-layer model for borehole ground heat exchangers with an inhomogeneous ground water flow. Energy. 47: 378-387.

Li, S.J., Fan, Y.S. and Zhang, D.G., 2007. Numerical simulation of relationship between thermal conductivity of geotechnical material and its porosity. Rock and soil mechanics. 28, 244-249.

Li, S.J., Liu, Y.X. and Yu, H., 2009. Numerical simulation of relationship between thermal conductivity of porous material and fractal dimension. Rock soil Mech. 30(5), 1465-1470.

Li, X., Zhao, J. and Zhou, Q., 2005. Inner heat source model with heat and moisture transfer in soil around the underground heat exchanger. Appl. Therm. Eng. 25, 1565-1577.

Liang, H., Hu, K., Qin, W., Zuo, Q. and Zhang, Y., 2017. Modelling the effect of mulching on soil heat transfer, water movement and crop growth for ground cover rice production system. Field crops research. 201, 97-107.

Lipiec, J. and Hatano, R., 2003. Quantification of compaction effects on soil physical properties and crop growth. Geoderma. 116, 107-136.

Lipiec, J., Hajnos, M. and Swieboda, R., 2012. Estimating effects of compacting on pore size distribution of soil aggregates by mercury porosimeter, Geoderma. 179-180, 20-27.

Liu, W.M., He, P. and Zhang, Z., 2002. A calculation method of thermal conductivity of soils. Journal of Glaciology and Geocryology. 24(6), 770-774.

Liu, B.C. and Liu, W., 2005. Study of heat and moisture transfer in soil with a dry surface layer. Int. J. Heat Mass Transfer. 48 (21-22), 4579-4589.

Liu, CH., Zhou, D. and Wu, H., 2011. Measurement and prediction of temperature effects of thermal conductivity of soils. Chin. J. Geotech. Eng. 33(12), 1877-1886.

Loukili Y., Woodbury A.D. and Snelgrove K.R., 2008. SABAE-HW: An enhanced water balance prediction in the Canadian Land Surface Scheme compared with existing models. Vadose Zone Journal, 7, 865–877.

Low, J.E., Loveridge, F.A.and Powrie, W., 2013. Measuring soil thermal properties for use in energy foundation design. Proceeding of the 18th International conference on soil mechanics and geotechnical engineering, Paris.

Lu, N. and Dong, Y., 2015. Closed-form equation for thermal conductivity of unsaturated soils at room temperature. J. Geotech. Geoenviron. Eng. http://dx.doi.org/10.1061/ (ASCE)GT.1943-5606.0001295.

Lu, S., Ren, T. and Gong, Y., 2007. An improved model for predicting soil thermal conductivity from water content at room temperature, SSSA. J. 71(1), 8-14.

Lu, S., Ren, T.S., Gong, Y.S. and Horton, R., 2007. An improved model for predicting soil thermal conductivity from water content at room temperature. Soil Sci Soc Amer. J. 1, 8–14.

Luikov, A.V., 1996. Heat and mass transfer in capillary-porous bodies. Pergamon Press, Oxford.

Lyzdba, D., Rajczakowska, M., Rozanski, A. and Stefaniuk, D. 2014. Influence of the Moisture Content and Temperature on the Thermal Properties of Soils: Laboratory Investigation and Theoretical Analysis. Procedia Engineering, 91, 298-303.

Maag, M. and Winther, F.P., 1999. Effect of temperature and water on gaseous emissions from soils treated with animal slurry. Soil Sci. Soc. Amer. J. 63, 858-865.

Mady, A. and Shein, E., 2016. Modeling soil thermal diffusivity as a fuction of soil moisture, Вестник Оренбургского государственного университета, 12: 200.

Maity, P. and Aggarwal, P., 2012. Variation of thermal properties of a sandy loam soil under different soil management practices. Indian J. Agric. 82,62-65.

Markle, J.M., Schincariol, R.A., Sass, J.H. and, Molson, J.W., 2006. Characterizing the two-dimensional thermal conductivity distribution in a sand and gravel aquifer. Soil science society of America journal. 70(4), 1281-1294.

Marshall, T. J. and Holmes, J.W., 1988. Soil Physics. 2nd ed. Cambridge Univ. Press, New York.

Meukam, P., Noumowe, A., Jannot, Y. and Duval, R. 2003. Thermophysical and mechanical characterization of stabilized clay bricks for buildings thermal insulation. Meter. Struct. 36, 453-460.

Middleton, H.E., 1930. Properties of soils which influence soil erosion. U.S. Department of Agr. Tech. Bull. 178. 16 p.

Midttomme, K., Roaldset, E. 1998. The effect of grain size on thermal conductivity of quartz sands and silts. Pet. Geosci. 4, 165-172.

Midttomme, K. and Roaldset, E. 1999. Thermal conductivity of sedimentary rock: uncertainties in measurement and modelling, Geol. Soc. Lond. 158, 45–60.

Minacapilli, M., Iovino, M. and Blanda, F., 2009. High resolution remote estimation of soil surface water content by a thermal inertia approach. Journal of hydrology. 379 (3-4), 229-238.

Nelson, D.W. and Sommer, L.E., 1982. Total carbon, organic carbon, and organic matter. p.539-579. In A.L. Page (ed) Methods of Soil Analysis. 2nd Ed. ASA Monogr. 9(2). Amer. Soc. Agron. Madison, WI.

Nelson, R.E., 1982. Carbonate and gypsum. Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties. 2nd ed. Page, AL., Miller, R.H. and Keeney, D.R. (eds). p.181-197. Agronomy No:9ASA-SSSA, Madison, Wisconsin.

Nusier, O.K. and Abu-Hamdeh, N.H., 2003. Laboratory techniques to evaluate thermal conductivity for some soils. Heat and Mass Transfer. 39, 119-123.

Ochsner, T.E., Horton, R. and Ren, T., 2001. A new perspective on soil thermal properties, Soil Sci. Soc. Amer. J. 65, 1641-1647.

Olsen, S.R. and Sommers, L.E., 1982. Phosphorus. In: Page AL, Miller RH, Keneey DR (eds) Methods of soil analysis, part 2. Agronomy 9, Am Soc Agron, Madison, WI, pp 403–430

Omer, T.F., 1981. The thermal properties of soils in cold regions. Cold regions science and technology. 5(1), 67-75.

Overduin, P.P.,, Kane, D.L. and van Loon, W.K.P., 2006. Measuring thermal conductivity in freezing and thawing soil using the soil temperature response to heating. Cold regions science and technology, 45, 8-22.

Pei, W., Yu, W., Li, Sh. and Zhou, J., 2013. A new method to model the thermal conductivity of soil-rock media in cold regions: An example from permafrost regions tunnel. Cold region science and technology, 95, 11-18.

Pereira, T.T.C., Schaefer, C.E.G.R., Ker, J.C., Almeida, C.C., Almeida, I.C.C. and Pereira, A.B., 2013. Genesis, mineralogy and ecological significance of ornithogenic soils from a semi-desert polar landscape at Hope Bay. Antarctic Peninsula. Geoderma. 209-210: 98-109.

Philip, J.R. and de Vries, D.A., 1957. Moisture movement in porous materials under temperature gradients. Trans. Am. Geophys. Union. 38, 222-232.

Ren, T., Noborio, K. and Horton, R. 1999. Measuring soil water content, electrical conductivity and thermal conductivity with a thermo-time domain reflectometry probe. Soil Sci. Soc. Amer. J. 63, 450-457.

Rhoades, J.D., 1982. Slouble salts. Methods of soil analysis. Part 2. Chemical and microbiological properties. 2nd edition. Agronomy No:9, 149-157,1159p, Madison, Wisconsin USA.

Richards, L. A., 1954. Diagnosis and Improvement of Saline and Alkaline Soils, USDA handbook. 78(2), 154.

Sakaguchi, I., Momose, T. and Kasubuchi, T., 2007. Decrease in thermal conductivity with increasing temperature in nearly dry sandy soil, Eur. J. Soil Sci. 58 (1),92–97.

Sarılar, Y., 2013. Toprakların Sıcaklık Değişiminin ve Bazı Isısal Özelliklerinin İncelenmesi Ondokuz Mayıs Üniversitesi Fen Bilimleri Enstitüsü Toprak Bilimi ve Bitki Besleme Anabilim Dalı, Yüksek Lisans Tezi Samsun.

Sayde, C., Gregory, C., Gil-Rodriguez, M., Tufillaro, N., Tyler, S., Van de Giesen, N. and Selker, J.S., 2010. Feasibility of soil moisture monitoring with heated fiber optics. Water Resources research. 46(6), 1-8.

Shiozawa, S. and Campbell, G., 1990. Soil thermal conductivity, Remote Sens. Rev. 5, 301-310.

Signorelli, S., Bassetti, S., Pahud, D. and Kohl, T., 2007. Numerical evaluation of thermal response tests. Geothermics. 36(2), 141-166.

Simas, F.N.B., Schaefer, C.E.G.R., Albuquerque Filho, M.R., Francelino, M.R., Ferenandes Filho, E.I. and Costa, L.M., 2007. Genesis, properties and classification of Cryosols from Admiralty Bay, Maritime Antarctica. Geoderma. 144, 116-122.

Slawinski, C., Witkowska-Walczak, B., Lipiec, J. and Nosalewicz, A., 2011. Effects of aggregate size on water movement in soils. Int. Agrophys. 25, 53-58.

Smith, D.M. and Allen, S.J., 1996. Measurement of sap flow in plant stems, J. Exp. Bot. 47, 1833–1844.

Smits, K.M., Sakaki, T., Howington, S.E., Peters, J.F. and Illangasekare, T.H., 2013. Temperature dependence of thermal properties of sands across a wide range of temperatures. Vadose Zone J. 12(1).

Stonea, P.J., Sorensena I.B. and Jamiesonb P.D., 1999. Effect of soil temperature on phenology, canopy development, biomass and yield of maize in a cool-temperate climate. Field Crops Research 63, 169-178

Şımarmaz. A., 2010. Arazi Koşullarında Toprağın Isısal Özelliklerinin Araştırılması ve Matematiksel Modellemesi. Selçuk Üniversitesi Fen Bilimleri Enstitüsü Yüksek Lisans Tezi Toprak Anabilim Dalı. Konya

Tan, X.J., Chu, Y.D. and Chen, W.Z., 2010. A new method to study thermal conductivity of geomaterials considering phase change. Rock and soil mechanics. 31(2): 70-75.

Tan, J.C., Tsipas, S.A., Golosnoy, I.O., Curran, J.A., Paul, S. and Clyne, T.W., 2006. A steady state Bi-substrate technique for measurement of the thermal conductivity of ceramc coatings, Surf. Coat. Technol. 201(3-4), 1414-1420.

Tarnawski, V.R. and Leong, W.H., 2000. Thermal conductivity of soils at very low moisture content and moderate temperatures. Transport Porous Med. 41(2), 137-147.

Tarnawski, V.R., Gori, F., Wagner, B. and Buchan, G.D. 2000. Modelling approaches to predicting thermal conductivity of soils at high temperatures, Int. J. Energy Res. 24 (5), 403–423.

Terefe, T., Mariscal-Sancho, I., Peregrina, F. and Espejo, R., 2008. Influence of heating on various properties of six Mediterranean soil: a laboratory study. Geoderma. 143, 273-280.

Thion, C., Cebron, A., Beguiristain, T. and Leyval, C., 2012. Long-term in situ dynamics of the fungal communities in a multi-contaminated soil are mainly driven by plants. FEMS Microbiol. Ecol. 82: 169-181.

Thomas, H.R. and Li, C., 1997. An assessment of a model of heat and moisture transfer in unsaturated soil. Geotechnique. 47, 113-131.

Thomas, H.R. and Rees, S.W., 2009. Measured and simulated heat transfer to foundation soils. Geotechnique, 59(4), 365-375.

Tien, Y.M., Chu, C.A. and Chuang, W.S., 2005. The prediction model of thermal conductivity of sand-bentonite based buffer material, in: France Clays in Natural and Engineered Barriers for Radioactive Waste Confinement. pp. 657.

Tong, F., Jing, I. and Zimmerman, R.W., 2009. An effective thermal conductivity model of geological porous medium for coupled thermo-hydro-mechanical systems with multiphase flow. Int. J. Rock. Mech. Min. Sci. 46(8), 1358-1369.

Tyson, E. Ochsner, R. Horton, R. and Tusheng R., 2001. A new perspective on soil thermal properties. Soil Sci. Soc. Amer. J. 65, 1641-1647.

Usowicz, B., Lukowski M.I., Rudiger, C., Walker J.P. and Marczewski, W. 2017. Thermal properties of soil in the Murrumbidgee River Catchment (Australia). International Journal of Heat and Mass Transfer. 115, 604–614.

Van doninck, J., Peters, J., De Baets, B., De Clercq, E.M., Ducheyne, E. and Verhoest, N., 2011. The potential of multitemporal Aqua and Terra MODIS appareent thermal inertia as a soil moisture indicator. International Journal of Applied Earth Observation and Geoinformation. 13, 934-941.

Van Wijk, W.R. and de Vries, D.A., 1963. Periodic Tempereature Variations in a Homogeneous Soil. In: Physics of plant environment (W.R. van Wijk (Ed.) North-Hol-land Publishing, Amsterdam, pp: 102-143.

Vlodek, R.T. and Bernhard, W., 1993. Modeling the thermal conductivity of frozen soils. Cold regions science and technology. 22(1), 19-31.

Votrubova J., Dohnal M., Vogel T. and Tesar M., 2012. On parameterization of heat conduction in coupled soil water and heat flow modelling. Soil and Water Research, 7, 125–137.

Walker, D.J.H., 1997. Dispersive soils in KwaZulu-Natal. Unpublished MSc thesis. University of Natal, Durban.

Wang, H., Qi, C., Wang, E. and Du, H., 2010. Study of heat and moisture transfer under the condition of high-temperature thermal storage. Acta Energiae solaris sin. 31(7), 824-827.

Wang, X.K., Li, Z.B. and Xing, Y.Y., 2015. Effects of mulching and nitrogen on soil temperature water content, nitrate-N content and maize yield in the Loess Plateau of China. Agric. Water Manage. 161, 53–64.

Weiss, J.D., 2003. Using fiber optics to detect moisture intrustion into a landfill cap consisting of a vegetative soil barrier. Journal of the air and waste management association. 53(9), 1130-1148.

Wild, A. 1988. Russell's Soil Conditions and Plant Growth, 11th ed. Longman scientific and technical, Harlow.

Wu, J. and Nofziger, D. L., 1999. Incorporating temperature effects on pesticide degradation into a management model. J. Environ. Qual. 28, 92-100.

Wu, W., Li, X., Charlier, R. and Collin, F., 2004. A thermo-hydro-mechanical constitutive model and its numercial modelling for unsaturated soils. Comput. Geotech. 31(2), 155-167.

Wu, D., Lai, Y. and Zhang, M. 2015. Heat and mass transfer effects of ice growth mechanisms in a fully saturated soil. Int. J. Heat Mass Transfer. 86, 699-709.

Xaman, J., Lira, L. and Arce, J., 2009. Analysis of the temperature distribution in a guarded hot plate apparatus for measuring thermal conductivity. Appl. Therm. Eng. 29(4), 617-623.

Yan, Q.Y., Yu, J.G. and Shang, D.J., 2000. The experiment research and calculation method on the effective thermal conductivities of basalt particle beds. J. Hebei. Univ. Technol. 29(5), 29-32.

Yılmaz, Ö., 2008. Toprak Kolonlarında Isısal Özelliklerin Belirlenmesi ve Modellenmesi. Selçuk Üniversitesi Fen Bilimleri Enstitüsü Yüksek Lisans Tezi Toprak Anabilim Dalı. Konya

Yoshikawa, K., Bolton, W.R., Romanovsky, V.E., Fukuda, M. and Hinzman, L.D., 2003. Impacts of wildfire on the permafrost in the boreal forests of interior Alaska. J. Geophys. Res. 108 (D1), 8148.

Zawadzki, S., B. Dobrzan., S. Kowalin., T. Skawina. and Ku nicki F., 1999. Gleboznawstwo. Podrecznik dla studentow. Wydanie IV poprawone zupelnione. Panstwowe Wydawnicto Rolnicze Lesne. Warszawa, 559 P. ISBN 830901703-0.

Zhang, N. and Wang, Z., 2017. Review of soil thermal conductivity and predictive models. International Journal of Thermal Sciences, 117, 172-183.

Zhang, Y.J., Yu, Z.W. and Huang, R., 2009. Measurement of thermal conductivity and temperature effect of geotechnical materials. Chin. J. Geotech. Eng. 31(2), 213-217.

Zhang, N., Yu, X.B., Pradhan, A. and Puppala, A.J. 2015. Thermal conductivity of quartz sands by thermo-TDR prob and model prediction. ASCE. J. Mater. Civ. Eng.

Zhang, N., Yu, X.B., Pradhan, A. and Puppala, A.J., 2016. A new generalized soil thermal conductivity model for sand-kaolin clay mixtures using thermo-time domain reflectometry probe test. Acta Geotech. 1-14.

Zhang, T., Cai, G., Liu, S. and J.Puppala, A. 2017. Investigation on thermal characteristics and prediction models of soils. International Journal of Heat and Mass Transfer 106, 1074–1086.

Zhao, J., Wang., H. and Li, X., 2008. Experimental investigation and theoretical model of heat transfer of saturated soil around coaxial ground coupled heat exchanger. Appl. Therm. Eng. 28(2-3), 116-125.

Zhao, Y.X., Yang, S.Z. and Zhang, W.R., 1995. An experimental study of rock thermal conductivity under different temperatures and pressures. Prog. Geophys. 10(1), 104-113.

Biography

Leila Imanparast was born in Ardebil/Iran at 1984. Her guidance and high school was spent in the talented schools and graduated of the high school at 2002. She started university life at 2002 in Mohaghegh Ardebili University, Agriculture faculty, soil science department. She ended B.Sc. at 2005 and startedworking at natural source and agriculture research center in Ardebil. She passed the extrance exam of master science and was began the master science period in soil physics and conservation branch in Tabriz University at 2009. She was graduated of master science at 2011. During 2011-2013, she worked as soil laboratory management in Ardebil and she started Ph.D period in soil physics branch at Ataturk University, Agriculture faculty, soil science and plant nutrition department at 2013. At the end of her Ph.D period, she started working at agricultural company in Ankara. Also, she is performing a project about soil organic amendment by cooperation the Turkey agriculture ministry, agronomy plant research center and Ankara University, agriculture faculty, soil science department, now.