THE EFFECTS OF GRASS AND RAINFALL PATTERN ON THE MATRIC SUCTION OF ACIDIC SOIL SLOPES

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ABSTRACT

Among the mechanism that leads to slope failures are that the matric suction starts to decrease when water infiltrates the soil. Although many studies have been carried out to improve stability of slope, most studies often ignore the influence of matric suction induced by vegetation. Grass can be classified into many different types and appearances. For this research, Bermuda grass and Signal grass were used to investigate matric suction due to rainfall by applying hydromulching on sloping ground. Despite numerous efforts in the past to investigate the influence of rainfall infiltration on slope stability, there was limited research on the effect of both rainfall infiltration and evaporation on sloping ground. This study provides an insight on how matric suction changes after applying hydromulching on the sloping ground of acidic soil slopes. A large-scale model (with four slope surfaces) and rainfall simulator were used to measure the matric suction of soil at a depth of 20 cm by a soil moisture sensor. This research investigate the variations in matric suction profiles under a loose and compact soil condition, treated and untreated dolomite, bare plot and a grassed surface in acidic soil slopes response to rainfalls pattern. The field monitoring results showed the ability of both (Signal & Bermuda) grass covers to maintain the matric suction on acidic soil slopes during rainfall. The rate of changes in suction for bare slope surface is much faster as compared to grass-covered slope surface. The finding showed the hydromulching creates grass cover on top of acidic soil slopes and the grass influence the matric suction. The thesis has contributed to some original outcomes. First, how distribution of matric suction changes in sloping ground after apply hydromulching. Second, implementation of an easy and effective matric suction measurement method by using sensors in field work. Last, the results of the study proved that the hydromulching method with additives such as dolomite, fertilisers can be used for this acidic soil.

ABSTRAK

Antara mekanisma yang membawa kepada kegagalan cerun adalah sedutan matrik mula berkurang apabila air menyusup dalam tanah. Walaupun banyak kajian telah dijalankan untuk meningkatkan kestabilan cerun, kebanyakan kajian sering mengabaikan pengaruh sedutan matriks yang disebabkan oleh tumbuh-tumbuhan. Rumput boleh diklasifikasikan dalam pelbagai jenis dan rupa. Untuk kajian ini, *Bermuda grass* dan *Signal grass* digunakan untuk menyiasat sedutan matriks disebabkan oleh hujan dengan menggunakan *hidromulching* di tanah cerun. Walaupun telah banyak usaha untuk menyiasat pengaruh infiltrasi hujan pada kestabilan cerun, terdapat kajian terhad mengenai kesan kedua-dua penyusupan dan penyejatan hujan di tanah cerun. Kajian ini memberi pemahaman tentang bagaimana perubahan sedutan matriks selepas penggunaan *hydromulching* di permukaan cerun tanah berasid. Model berskala besar (dengan empat permukaan cerun) dan simulasi hujan digunakan untuk mengukur sedutan matriks pada kedalaman 20 cm dengan penyesan kelembapan tanah. Kajian ini menyiasat variasi profil sedutan matrik di bawah tanah yang longgar dan padat, dolomit yang dirawat dan tidak dirawat, plot terdedah dan permukaan berumput di kawasan tanah cerun berasid yang bertindakbalas terhadap corak hujan. Hasil pemantauan lapangan menunjukkan keupayaan kedua-dua rumput dapat mengekalkan sedutan matriks pada cerun tanah berasid semasa hujan. Kadar perubahan sedutan matrik pada permukaan terdedah lebih cepat berbanding dengan permukaan cerun yang dilindungi. Temuan menunjukkan *hydromulching* memberi penutup rumput di atas tanah cerun berasid dan rumput mempengaruhi sedutan matriks. Tesis ini telah menyumbang kepada beberapa hasil. Pertama, bagaimana pengedaran perubahan sedutan matrik dalam cerun tanah selepas penggunaan hydromulching. Kedua, pelaksanaan kaedah pengukuran yang mudah dan berkesan dengan menggunakan alat penyesan di kerja lapangan. Akhirnya, hasil kajian membuktikan bahawa kaedah *hydromulching* dengan tambahan seperti dolomit dan baja boleh digunakan untuk tanah berasid ini.

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LIST OF SYMBOLS AND ABBREVIATIONS

h - Soil suction or total suction

R - Universal gas constant

T - Absolute temperature

v_{wo} - Specific volume of water or the inverse of the density of water

ω_v - Molecular mass of water vapor

u_v - Partial pressure of pore water vapor

u_{vo} - Saturation pressure of water vapor over a flat surface of pure water at the same temperature

π - Osmotic suction

M_c - Moisture content (%)

LL - Liquid Limit

PL - Plastic Limit

PI - Plasticity Index

c' - Effective cohesion

ϕ' - Angle of internal friction associated with the net normal stress $(_f - u_a)$

ϕ^b - Angle indicating the rate of increase in shear strength relative to matric suction,$(u_a - u_w)$.

k_w - Coefficient of permeability with respect to the water phase

$\partial h_w/\partial y$ - Hydraulic head gradient in the y-direction

h_w - Hydraulic head (the sum of the elevation and pore-water pressure heads)

x and y - Cartesian coordinates in the x- and y-direction

ρw - Density of water
g - Gravitational acceleration

m_2^w - Coefficient of water volume change with respect to a change in matric suction or the slope of the SWCC.

β - Sloping distance across the base of a slice

R - Radius for a circular slip surface or the moment arm associated with the mobilised shear force on the base of each slice

N - Total normal force on the base of the slice

W - Total weight of a slice of width b and height h

x - Horizontal distance from the centreline of each slice to the centre of rotation or to the centre of the moments

f - Perpendicular offset of the normal force from the centre of rotation or from the centre of moments

α - Angle between the tangent to the centre of the base of each slice and the horizontal

m_1 - Mass of the pycnometer bottle (g)

m_2 - Mass of pycnometer bottle and dry soil (g)

m_3 - Mass of pycnometer bottle, soil and water (g)

m_4 - Mass of pycnometer bottle when full of water only (g)

a - Area of cross-section of standpipe tube

A - Area of cross section of sample

h_1 - Heights of water above datum in standpipe at time t_1

h_2 - Heights of water above datum in standpipe at time t_2

L - Heights of sample

t - Elapsed time (minutes)

ms - Mass of core cutter and wet soil

mc - Mass of core cutter

Vc - Volume of core cutter

w - Moisture content

ί - Average rainfall intensity

Q - Sprayed discharge

σ - Standard deviation

CU - Uniformity coefficient

CV - Coefficient of variation of the rainfall intensity

CHAPTER 1

INTRODUCTION

1.1 Background of study

In tropical regions which experienced period of intense or prolonged rainfall events, heavy rainfalls along with hot temperature and other humid climatic conditions result in the formation of deep residual soil profile. This residual soil commonly exists is unsaturated conditions, with presence of negative pore-water pressure or matric suction. The negative pore-water pressure contributes additional shear strength to the unsaturated residual soil. This additional shear strength normally ceases or reduces considerably enough to trigger slope failure due to loss of matric suction as wetting front progresses from the ground surface (Fredlund & Rahardjo, 1993; Rahardjo *et al.*, 2005; Fredlund, Rahardjo & Fredlund, 2012). A rainfall infiltration process in unsaturated soils is a complex process which heavily affects slope stability conditions (Cuomo & Della Sala, 2013). The failure mechanisms are mainly due to the loss of matric suction of soils by rainwater. When rainwater infiltrates into the slopes, it is known that it will start to saturate the soil hence, reduce the matric suction.

The effect of negative pore-water pressure is often ignored in slope ground studies. There is a perception among geotechnical engineers that negative pore-water pressures will dissipate with rainfall infiltration and cannot be relied upon in design considerations (Zhang *et al.*, 2004). The wetting front of rainwater will continue to move into the soil even after the rain has stopped. Due to rainfall, different types of slope instability phenomena (either slope failures or erosion-like phenomena) are triggered which cause, in turn, different flow-like mass movements (Cascini *et al.*, 2014). Movement of the wetting front stops when an equilibrium or steady state condition is achieved. Basically, it is known that infiltration impairs slope ground. However, since it is often not measured off directly from the field, its assessment often relies on the vague correlation with rainfall and runoff. The correlation between rainfall and sloping ground involves a large number of factors (Huat, Ali & Low, 2006). Some of these factors such as rainfall duration and intensity, slope surface cover, degree of saturation, slope angle, permeability ratios and perched water table are extremely difficult to evaluate.

Unsaturated soil mechanics is often applied to geotechnical problems such as embankments, dams, pavements, foundations, landfills, slopes and nuclear waste disposals. Analyzing such problems requires information about soil suction variations. This explains why the significant effort has been made from all over the world on suction measurement techniques under field conditions. Unsaturated soil mechanics have been studied intensively in recent years. The behaviour of unsaturated soil in the field is extremely delicate to the flex changes of groundwater table and rainfall infiltration (Wu & Selvadurai, 2016). A better understanding of soil mechanics would mean a better design of slopes in terms of cost and safety. There are different ways of approaching the unsaturated zone, but Lu and Likos (2004) suggest that it can be pictured as two different zones: a seasonal steady zone and a seasonal unsteady zone. In the unsteady zone near the surface, various time-dependent factors as relative humidity, temperature, precipitation and evaporation among others cause the soil suction to fluctuate. The steady zone is situated below this zone and is relatively time independent. Properties such as the steady recharge rate, surface topography, soil type and the groundwater table strongly influence the suction profile in this zone.

Natural soils in an unsaturated state are common in arid or semi-arid areas where the groundwater table is often many meters deep. Around one-third of the earth's surface is situated in arid or semi-arid regions where the potential evaporation exceeds the precipitation (Alonso & Delage, 1995). However, any soil near the ground surface in a relatively dry environment is liable to have a negative pore water pressure (water pressure relative to a datum of atmospheric air pressure) and could experience de-saturation or air entry into the pore spaces. Though the soil may be saturated for a certain height above the water table, air will enter pore spaces if the pore water pressure drops sufficiently (Vanapalli & Oh, 2012). Figure 1.1 illustrates the change from a positive pore water pressure below the water table to a negative pore water pressure above the water table. While the plot indicates a reduction in negative pore water pressure close to the ground surface where precipitation would increase the degree of saturation, increased desiccation due to evaporation can be expected to occur in a hot environment (Bell, Cripps & Culshaw, 1986). Negative pore water pressure is the key to understanding unsaturated soil behaviour.

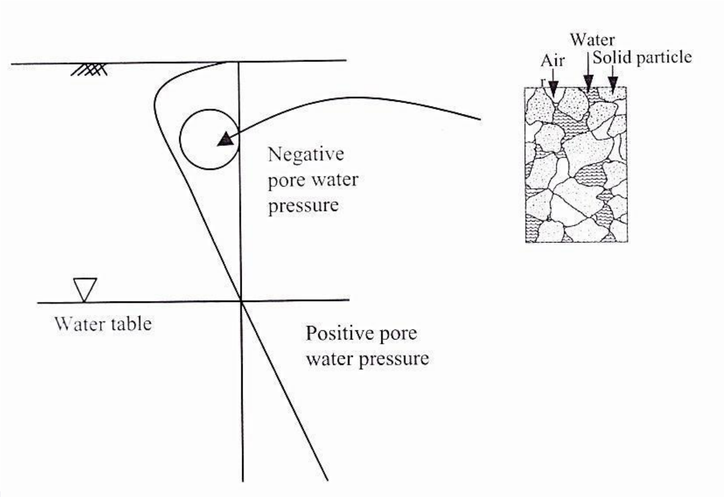

Figure 1.1: Unsaturated soils in the ground (Vanapalli & Oh, 2012)

Climate plays an important role in the formation of unsaturated soil (Ng & Menzies, 2007). Evaporation during hot weather can cause the ground to dry out, leading to the shrinkage of fine-grained soils which ultimately results in shrinkage cracking. Subsequent wetting, following rain, leads to the swelling and closure of cracks. However, this does not necessarily eradicate suction induced soil structure. Future climate changes due to global warming could potentially cause significant changes to the soil moisture regime and soil conditions in large areas. The uptake of water by vegetation can also lead to significant ground de-saturation due to evapotranspiration while the removal of vegetation can lead to subsequent re-saturation which causes potential stability problems.

The erosion of residual or acidic soil slopes has become a serious problem (Saifuddin & Normaniza, 2016; Jing *et al.*, 2019). Furthermore, some of the areas are highly acidic as the soil has a low pH. In fact, residual acidic soil slopes which are not covered by vegetation greatly increase soil erosion rates (Osman, Saifuddin & Halim, 2014). Slope failures or soil erosion could cause damage to human lives as well as property. This is because acidic soil slope areas are not able to support the development and growth of any vegetation. According to Craswell & Pushparajah (1989), acidic land covers expansive areas in southern China, Thailand, Laos, Vietnam and even Malaysia, particularly on the upper slopes of hillsides. The formation process of residual soil is strongly influenced by climate, rainfall, tides and landforms.

The application of crop residue mulches can contribute to improve the soil fertility and soil properties that affect crop productivity (Jordán, Zavala & Gil, 2010; Mulumba & Lal, 2008). The mulching of agricultural lands increases the content of soil organic matter (Saroa & Lal, 2003) that helps to improve soil aggregation (Mulumba & Lal, 2008), and hence positively affects soil porosity, which improves water infiltration, reduces runoff and controls soil erosion (Edwards *et al.*, 2000; Jordán *et al*., 2010; Mulumba & Lal, 2008; Rees *et al.*, 2002;). Hydromulches, such as those made from wood products combined with water, are a surface cover commonly applied in both urban settings and disturbed soils to reduce erosion and provide grass seed (hydroseeding; Megahan, Wilson & Monsen, 2001; Prats *et al.*, 2016). Although hydromulches have been studied extensively as a way to reestablish vegetation communities, their impact on the moderation of rainfall and matric suction has not been described. The effects of mulching on soil moisture depend on precipitation and climatic factors. Mulching favorably influences soil moisture regime by controlling surface evaporation rate; in summer, mulching conserves soil moisture by reducing the evaporation rate. Mulches improve soil-moisture retention capacity as well as soil structure and suppress weed growth (Mutetwa & Mtaita, 2014). The amount of soil-moisture conservation under different mulching materials differs in different soil types and climatic conditions. In general, the mulching treatments store higher soil moisture compared to the bare soil (no mulch) (Chakraborty *et al.*, 2008; Zhao *et al.*, 2014).

In general, the main causes of landslides in most unsaturated slopes are often initiated by the process of infiltration or rising pore water pressures (Schnellmann *et al.*, 2010; Lourenc, Wang & Kamai, 2015). These unsaturated slopes have soils that have different water contents from the ground surface (dry condition) to a considerable depth (saturated), and the pore water pressure in this unsaturated zone is generally negative with respect to atmospheric pressure. The presence and magnitude of suction pressure have been found to be important to the stability of such kind of slopes

(Sorbino & Nicotera, 2013). Infiltration of rainfall leads to a reduction in soil matric suction, or the rising of the water table results in an increase in pore water pressure (from negative to positive at the potential shear surface). This, in turn, results in a decrease in shear resistance on the potential failure surface to a point where equilibrium can no longer be sustained in the slope and then failures can occur (Fredlund & Rahardjo, 1993). Therefore, studies of SWCCs can assist in the understanding of pore water pressure distributions in the slope.

1.2 Problem statement

It has been established that rainfall infiltration trigger slope failures by inducing the increase in moisture content and reducing or eliminating matric suctions. However, the distribution of matric suction is also known to be influenced by evaporation process. Despite of many works done on the influence of rainfall infiltration on slope stability, not much effort have been given to combine the effect of rainfall infiltration and evaporation on the sloping ground. The difference between the downward flux (precipitation) and the upward flux (evaporation and transpiration) is thought to have influence on the suction distribution in soil especially near ground surface. This study gave insight on how matric suction changes on sloping ground after apply hydromulching. Furthermore, soil acidity will directly affect plant growth. Raindrops falling on a bare soil break down the structure of the surface soil and detach particles. If the land is sloping and the water cannot be immediately absorbed by the soil, the water moves off down the slope in the form of run-off, carrying dislodged particles with it. To minimize this problem, remediation using hydromulching method of acidic soil need to be done whether it successful or not. There is no information available on the effect hydromulching of the matric suction on acidic soil slopes. Therefore there was a need to investigate the changes matric suction on bare slope and grass slopes. Most of the slope failures in unsaturated tropical residual soil in Malaysia are mainly due to infiltration, especially during intense and prolonged rainfall which reduces the soil matric suction. The implementation of unsaturated soil mechanics in the field of engineering is hampered by the lack of field data. Therefore, there is a need to assess the capability of other models and approaches.

REFERENCES

Abouziena, H. F. & Radwan, S. M. (2015). Allelopathic effects of sawdust, rice straw, burclover weed and cogon grass on weed control and development of onion. *Int. J. ChemTech Res. 7*, pp. 337–345.

Adekalu, K. O., Olorunfemi, I. A. & Osunbitan, J. A. (2007). Grass mulching effect on infiltration, surface runoff and soil loss of three agricultural soils in Nigeria. *Bioresources Technol, 98*, pp. 912–917.

Affendi, A. & Faisal, A. (1994). Field measurement of soil suction, *Proc, 13th Int. Conf. Soil Mcch Found Eng.,* New Delhi, India, pp.1013-1016

Agriinfo. (2015). *Soil Structure Classification of soils.* Amazon Publishers.

Aldaood, A., Bouasker, M. & Al-mukhtar, M. (2014). Soil – water characteristic curve of lime treated gypseous soil. *Applied Clay Science, 102*, pp. 128–138.

Al-Shamrani, M. A. & Dhowian, A. W. (2003). Experimental study of lateral restraint effects on the potential heave of expansive soils. *Engineering Geology, 69(1–2),* pp. 63–81.

Alva, A. K., C. J. Asher & Edwards, D.G. (1986). The role of calcium in alleviating aluminum toxicity. Aust. *J. Agric. Res. 37*, pp. 375-383.

Alonso, E. E. & Delage, P. (1995). Effect of Rain Infiltration on the Stability of Slopes, Unsaturated Soils. *Proc. 1st Int. Conf. on Unsaturated Soils (UNSAT 95). Rotterdam: Balkema, 1*, pp. 241-249.

Anari, P. L., Darani, H. S. & Nafarzadegan, A. R. (2011). Application of ANN and ANFIS models for estimating total infiltration rate in an arid rangeland ecosystem. *Res. J. Environ. Sci., 5*, pp 236-247.

Anderson, N. P., Hart, J. M., Sullivan, D. M., Christensen, N. W., Horneck, D. A. & Pirelli, G. J. (2013). Applying Lime to Raise Soil pH for Crop Production (Western Oregon).

Aoki, A. M. & Sereno, R. (2006). Infiltration evaluation as an indicator of soil quality using a rain microsimulator. *Agriscientia*, *23*, pp. 23-31.

Archive, E. O. (2011). Influence of water table level and soil properties on emissions of greenhouse gases from cultivated peat soil, pp. 923–931

Aristizábal, E. G. (2012). Simulation of Rainfall and Seepage Flow on Unsaturated Soil by A Seepage - Deformation Coupled Method. *En Suelos Parcialmente Saturados Usando, 11(20)*, pp. 43–55.

Arnaez, J., Lasanta, T. Ruiz-Flaño, P. & Ortigosa, L. (2007). Factors affecting runoff and erosion under simulated rainfall in Mediterranean vineyards. *Soil Tillage Res. 93,* pp. 324-334.

Ashrafuzzaman, M., Abdulhamid, M., Ismail, M. R. & Sahidullah, S. M. (2011). Effect of plastic mulch on growth and yield of chilli (Capsicum annuum L.). *Braz. Arch. Biol. Technol. 54,* pp. 321–330.

Azhar, A. T. S., Hazreek, Z. A. M., Aziman, M., Haimi, D. S. & Hafiz, Z. M. (2016a) Acidic Barren Slope Profiling using Electrical Resistivity Imaging (ERI) at Ayer Hitam area Johor, Malaysia

Azhar, A. T. S., Fazlina, M. I. S., Aziman, M., Azman, K. & Hazreek. (2016). Preliminary Analysis on Matric Suction for Barren Soil. *IOP Conference Series: Materials Science and Engineering, 160(1)* pp. 2–10.

Azman, E. A., Jusop, S. & Ishak, C. F. (2014). Increasing Rice Production Using Different Lime Sources on an Acid Sulphate Soil in Merbok , Malaysia, *37*(2), pp. 223–247.

Bandyopadhyay, K. K., Hati, K. M. & Singh, R. (2009). Management options for improving soil physical environment for sustainable agricultural production: a brief review. *J. Agric. Phys. 9,* pp. 1–8.

Bakr, N., Elbana, T. A., Arceneaux, A. E., Zhu, Y., Weindorf, D. C. & Selim, H. M. (2015). Runoff and water quality from highway hillsides: influence compost/mulch. *Soil Tillage Res. 150,* pp. 158–170.

Barral, M. T., M. Arias, & Guérif, J. (1998). Effects of iron and organic matter on the porosity and structural stability of soil aggregates. *Soil & Tillage Research, 46,* pp. 261-272.

Barthès, B. G., E. Kouakoua, M. C. Larré-Larrouy, T. M. Razafimbelo, E. F. & Azontonde, A. (2008). Texture and sesquioxide effects on water-stable aggregates and organic matter in some tropical soils. *Geoderma, 143,* pp. 14-25.

Battany, M. C. (2000). Development of a portable eld rainfall simulator for use in hillside vineyard runoff and erosion studies. *Hydrol Process 14(6)*. pp. 1119–29

Begum, S. A., Ito, K., Senge, M. & Hashimoto, I. (2001). Assessment of selected mulches for reducing evaporation from soil columns and dynamics of soil moisture and temperature. *Sand Dune Res., 48,* pp. 1–8.

Bengough, A. G. (2012). Water dynamics of the root zone: rhizosphere biophysics and its control on soil hydrology. *Vadose Zone Journal, 11(2).*

Berga, L., Siriri, D. & Ebanyat, P. (2001). Effect of soil amendments on bacterial wilt incidence and yield of potatoes in southern western Uganda. *African Crop Science Journal, pp. 267–278.*

Bell, F. G., Cripps, J. C. & Culshaw, M. G. (1986). A review of the engineering behaviour of soils and rocks with respect to groundwater, *Groundwater in Engineering Geology*. pp. 1–23

Bear, J. (1972). Dynamics of fluids in porous media. *American Elsevier Publishing Company,* Inc., New York.

Benik, S. R., Wilson, B. N., Biesboer, D. D., Hansen, B. & Stenlund, D. (2003). Evaluation of erosion control product using natural rainfall events. *Journal of soil and water conservation, 58*, pp. 98-105

Bittelli, M., Ventura, F., Campbell, G. S., Snyder, R. L., Gallegati, F. & Pisa, P. R. (2008). Coupling of heat, water vapor, and liquid water fluxes to compute evaporation in bare soils. *Journal of Hydrology, 362(3–4),* pp. 191-205.

Blavet, D., De Noni, G., Le Bissonnais, Y., Leonard, M., Maillo, L., Laurent, J. Y., Asseline, J., Leprun, J. C., Arshad, M. A. & Roose, E. (2009). Effect of land use and management on the early stages of soil water erosion in French Mediterranean vineyards. *Soil Tillage Res. 106,* pp. 124–136.

Blaskó, L. (2011). Soil science, Debreceni Egyetem. Agrár- és Gazdálkodástudományok Centruma.

Blanquies, J., Scharff, M. & Hallock, B. (2003). The design and construction of a rainfall simulator. International erosion control association (IECA), Thirty fourth Annual conference and exposition, Las Vegas, Nevada, pp. 63-70,

Blight, G. E. (2003). The vadose-zone soil-water balance and transpiration rates of vegetation. *Géotechnique, 53(1),* pp. 55-64.

Blight, G. E. (1997) Interaction between the atmosphere and the earth. *Ge´otechnique (47),* pp. 715–767

Boardman, D. I., Glendinning, S. & Rogers, C. D. F. (2001). Development of stabilisation and solidification in lime-clay mixes. *Géotechnique, 50(6),* pp. 533-543

Bombino, G., Denisi, P. & Alfonso, G. (2019). Water Infiltration and Surface Runoff in Steep Clayey Soils of Olive Groves under Different Management Practices

Brady, N. C. & Weil, R.R. (2008). *The Nature and Properties of Soils Pearson.* Practice Hall.

Brien, P. L. O., Acharya, U., Alghamdi, R., Rashid, A., Sanyal, D., Wirtz, J. & Desutter, T. M. (2018). Hydromulch Application to Bare Soil: Soil Temperature Dynamics and Evaporative Fluxes, pp. 17–21. https://doi.org/10.2134/ael2018.03.0014

Brönnimann, C. S. (2011). Effect of Groundwater on Landslide Triggering PAR, *5236*.

Bulut, R., & Leong, E. C. (2009). Indirect measurement of suction. *Laboratory and Field Testing of Unsaturated Soils*, pp. 21–32. https://doi.org/10.1007/978-1-4020-8819-3_3

Byrne, M. P. & O'Gorman, P. A. (2015). The Response of Precipitation Minus Evapotranspiration to Climate Warming : Why the Wet-Get-Wetter , Dry-Get-Drier, Scaling Does Not Hold over Land, pp. 8078–8092.

Cárdenas, E. & Díaz, F. (2015). Tropical Pastures Program Annual Report.

Cascini, L., Sorbino, G., Cuomo, S. & Ferlisi, S. (2014). Seasonal effects of rainfall on the shallow pyroclastic deposits of the Campania region (southern Italy). *Landslides, 11*(5), pp. 779–792.

Cecconi, M. & Russo, G. (2008). Prediction of soil-water retention properties of a lime stabilised compacted silt. In: Toll, *et al.* (Eds.), Unsaturated Soils: *Advance in Geo-Engineering.* p.p 271–276.

Chalker-Scott, L. (2007). Impact of mulches on landscape plants and the environment-a review. *J. Environ. Horti, 25*, pp. 239–249.

Chakraborty, R. C. & Sadhu, M. K. (1994). Effect of mulch type and color on growth and yield of tomato (Lycopersicon esculentum). *Indian J. Agric. Sci., 64*, pp. 608–612.

Chakraborty, D., Nagarajan, S., Aggarwal, P., Gupta, V. K., Tomar, R. K., Garg, R. N., Sahoo, R. N., Sarkar, A., Chopra, U. K., Sarma, K. S. S. & Kalra, N. (2008). Effect of mulching on soil and plant water status, and the growth and yield of wheat (Triticum aestivum L.) in a semi-arid environment. *Agric. Water Manag., 95*, pp. 1323–1334.

Chen, Y. (2018). Soil Water Retention Curves Derived as a Function of Soil Dry Density. *GeoHazards 2018, 1(1),* pp. 3-19.

Christiansen, J. E. (1942). Irrigation by Sprinkling. University of California Agricultural Experiment Station: Berkeley, CA; Bulletin 670

Christofaki, M. I. (2011). Effect of Heavy Metal Stress in Plant Metabolism of Solanaceous Plant Species with Emphasis on Nitrogen Assimilation. Cranfield University.

Chin, F. Y. (2014). Justification, government policy, measures and strategy for the development of grazing reserves in Peninsular Malaysia. *Proc. of the 1st Meeting of Regional FAO Working Group on Grazing and Feed Resources in S.E. Asia, Serdang, Malaysia.*

Chiorean, V., Zhu, H. & Shi, B. (2018). Analysis of Infiltration-Suction Response in Unsaturated Residual Soil Slope in Gelugor , Penang.

Chiu, P. K. B. (2004). *Slope bioengineering in Hong Kong : A study of substrate properties and vegetation development.* The Chinese University of Hong Kong: Master Thesis

Chu, C. Y. & Ko, T. H. (2018). Evaluation of Acid Leaching on the Removal of Heavy Metals and Soil Fertility in Contaminated Soil, *Journal of Chemistry,* vol. 8.

Clark, O. R. (1940). Interception of rainfall by prairie grasses, weeds, and certain crop plants. *Ecological Monographs, 10,* pp. 243-277.

Clark, R. B. (1984). Physiological aspects of calcium and magnbesium and molybdenum deficiencies in plants. *Soil Acidity and Liming,* pp. 99–170.

Comino, J. R., Iserloh, T., Morvan, X., Issa, O. M., Naisse, C., Keesstra, S. D. & Prosdocimi, M. (2016). Soil Erosion Processes in European Vineyards : A Qualitative Comparison of Rainfall Simulation.

Cook, H. F., Valdes, G. S. B. & Lee, H. C. (2006). Mulch effects on rainfall interception, soil physical characteristics and temperature under Zea mays L. *Soil Tillage Res., 91*, pp. 227–235.

Cornelis, W. M., Erpul, G. & Gabriels, D. (2004). The I.C.E. Wind tunnel for wind and water interaction research. In Visser, S.M., and W.M. Cornelis (Eds.) Wind and rain interaction in erosion (trmp 50). Tropical Resource Management Papers, Wageningen University and Research Centre, Wageningen, The Netherlands. pp. 59-68.

Cornelis, J. T., Titeux, H. & Ranger, J. (2011). Identification and distribution of the readily soluble silicon pool in a temperate forest soil below three distinct tree species. *Plant Soil, 342,* pp. 369–378.

Craswell, E. & Pushparajah, E. (1989). Management of Acid Soils. *Australian Centre for International Agricultural Research, 13,* pp. 118.

Cranfill, R. (1991). Flora of Hardin County, Kentucky. *Castanea, 56,* pp. 228-267.

Crowder, L.V., Chaverra, H. & Lotero, J. (1970). Productive improved grasses in Colombia. *Proc. of the 11th International Grassland Congress.* Queensland, Australia, pp. 13–23.

Croney, D., Coleman, J. D. & Black, W. P. M. (1958). Movement and distribution of water in soil in relation to highway design and performance, in Water and Its Conduction in Soils, Special Report No. 40, Highway Research Board, Washington, DC, pp. 226–252.

Cui, Y. J. & Zornberg, J. G. (2008). Water balance and evapotranspiration monitoring in geotechnical and geoenvironmental engineering. *Geotechnical and Geological Engineering, 26(6),* pp. 783–798.

Cui, Y. J., Lu, Y. F., Delage, P. & Riffard, M. (2005). Field simulation of in situ water content and temperature changes due to ground-atmospheric interactions. *Géotechnique, 55(7),* pp. 557–567. doi:10.1680/geot.2005.55.7.557.

Cui, Y., Tang, A., Mantho, A. T. & Laure, E. D. (2007). Monitoring field soil suction using a miniature tensiometer, pp. 1–15.

Cuisinier, O. & Masrouri, F. (2005). Hydromechanical behaviour of a compacted swelling soil over a wide suction range. *Engineering Geology, 81(3),* pp. 204-212.

Cuomo, S. & Della-Sala, M. (2013). Rainfall-induced infiltration, runoff and failure in steep unsaturated shallow soil deposits. *Engineering Geology*, *162*, pp. 118–127.

Dasberg, S. & J. W. Bakker. (1970). Characterizing soil aeration under changing soil moisture conditions for bean growth. *Agronomy Journal, 62,* pp. 689-692.

Dahiya, R., Ingwersen, J. & Streck, T. (2007). The effect of mulching and tillage on the water and temperature regimes of a loess soil: experimental findings and modeling. *Soil Tillage Res. 96,* pp. 52–63.

Dai, Z. J., Chen, S. X. & Li, J. (2017). The water storage capability and hydraulic conductivity of different expansive soils, pp. 25–30.

Daene, R. A. (2005). Papermaking and finishing, In: Considine, G.D. (Eds.), Van Nostrand's Encyclopedia of Chemistry. *5th edition Wiley-Interscience*, pp. 1205–1208.

Danh, T., Cui, Y., Minh, A., Audiguier, M. & Cojean, R. (2014). Effects of lime treatment on the microstructure and hydraulic conductivity of Héricourt clay. *Journal of Rock Mechanics and Geotechnical Engineering, 6*(5), pp. 399–404.

Dasberg, S. & Bakker, J. W. (1970). Characterizing soil aeration under changing soil moisture conditions for bean growth. *Agronomy Journal, 62*, pp. 689-692.

De Oliveira, O. C., De Oliveira, I. P., Alves, B. J. R., Urquiaga, S. & Boddey, R. M. (2004). Chemical and biological indicators of decline/degradation of Brachiaria pastures in the Brazilian Cerrado. *Agric. Ecosyst. Environ, 103,* pp. 289–300.

Delage, P., Romero, E. & Tarantino, A. (2008). Recent developments in the techniques of controlling and measuring suction in unsaturated soils. *1st European Conference on Unsaturated Soils,* pp. 33–52.

During, C., Jackson, B. L. J. & Dyson, C. B. (1984). Effect of lime and monocalcium phosphate on soil moisture. *New Zealand journal of agricultural research, 27,* pp. 383- 387.

Duncan, J. M., Wright, S. G. & Brandon, T. L. (2014). Soil Strength and Slope Stability.

Egeli, I. & Pulat, H. F. (2012). Mechanism and modelling of shallow soil slope stability during high intensity and short duration rainfall. *Scientia Iranica, 18*(6), pp. 1179–1187.

Edwards, L., Burney, J. R., Richter, G. & MacRae, A. H. (2000). Evaluation of compost and straw mulching on soil-loss characteristics in erosion plots of potatoes in Prince Edward Island, Canada. Agric. *Ecosyst. Environ. 81*, pp. 217–222.

Elbyhagi, M. & Bridges, E. (2018). Effect of antecedent rainfall on pore-water pressure distribution characteristics in residual soil slopes under tropical rainfall, *1*(1), pp. 3–9.

Elsharief, A., Abdelaziz O. A. & Dafalla M. A. (2015). The influence of matric suction on the shear strength of highly plastic compacted swelling clays.

Esteves, M., Planchon, O., Lapetite, J. M., Silvera, N. & Cadet, P. (2000). Large Rainfall Simulator Design and Field, *Rainfall Simulation in Geomorphology, 690*, pp. 681–690.

Fabian, E., Aristizabal, G., Alberto, C., Jerez, R., Alonso, M. & Brand, B. (2011). Influence of Rainfall Intensity on Infiltration and Deformation of Unsaturated Soil Slopes. *Revista DYNA*, pp. 116–124.

Fageria, N. K. & Baligar, V. C. (2008). Ameliorating soil acidity of tropical oxisols by liming for sustainable crop production. in Advances in Agronomy, D. L. Sparks, (Ed)., Academic Press, São Paulo, Brazil. pp. 345–389.

Faisal , Low, T. H. & Savaranan, M. (2000). Measurement of suction and infiltration on slopes of unsaturated residual soils. pp. 140-143.

Faizun A. H. (2014). Phytoremediation Technique to Remediate the Acidic Soil Sampled at Ayer Hitam, Johor. Universiti Tun Hussien Onn Malaysia

Fatahi, B., Khabbaz, H. & Indraratna, B. (2010). Bioengineering ground improvement considering root water uptake model. *Ecol. Eng., 36*, pp. 222-229.

Feddes, R. A., Kowalik, P., Kolinska-Malinka, K. & Zaradny, H. (1976). Simulation of field water uptake by plants using a soil water dependent root extraction function. *Journal of Hydrology, 31(1)*, pp. 13-26.

Feki, M., Ravazzani, G., Ceppi, A., Milleo, G. & Mancini, M. (2018). Impact of Infiltration Process Modeling on Soil Water Content Simulations for Irrigation Management. *Water, 10*(7), pp. 850-860.

Fister, W., Iserloh, T., Ries, J. B. & Schmidt, R. G. (2012). A portable combined wind and rainfall simulator for in situ soil erosion measurements. *Catena. 91*, pp. 72-84

Fredlund, D. G., Rahardjo, H., Leong, E.C. & Ng, C. W. W. (2001). Suggestions and recommendations for the interpretation of soilwater characteristic curves. In *Proceedings of the 14th Southeast Asian Geotechnical Conference, Vol. 1*, pp. 503–508

Fredlund, D. G. (2006). Unsaturated Soil Mechanics in Engineering Practice. *Journal of Geotechnical and Geoenvironmental Engineering*, *132*(3), pp. 286-321

Fredlund, D. G. (2013). Interpretation of soil-water characteristic curves when volume change occurs as soil suction is changed, pp. 15–31.

Fredlund, D. G., Rahardjo, H. & Fredlund, M. D. (2012). *Unsaturated Soil Mechanics in Engineering Practice*.

Fredlund, D. G. & Rahardjo, H. (1993). *Measurements of Soil Suction, in Soil Mechanics for Unsaturated Soils*, John Wiley & Sons, Inc., Hoboken, NJ, USA.

Fredlund, D.G. & Xing, A. (1994) Equations for the Soil-Water Characteristic Curve. *Canadian Geotechnical Journal, 31*, pp. 521-532.

Gallipoli, D., Gens, A., Sharma, R. S. & Vaunat, J. (2009). An Elasto-Plastic Model for Unsaturated Soil Incorporating The Effects of Suction and Degree of Saturation on Mechanical Behaviour,*53*, pp. 123–135.

Gallipoli, D. & Mancuso, C. (2011). Soil suction monitoring for landslides and slopes. *Engineering Geology and Hydrogeology*, *44*, pp. 1–13.

Garg, A., Coo, J. L. & Ng, C. W. W. (2015). Field study on influence of root characteristics on soil suction distributions in slopes vegetated with Cynodon dactylon and Schefflera heptaphylla. *Earth Surface Processes and Landforms,40(12)*, pp. 1631–1643

Garrigues, E., Doussan, C. & Pierret, A. (2006). Water uptake by plant roots I–Formation and propagation of a water extraction front in mature root systems as evidenced by 2D light transmission imaging. *Plant and soil, 283(1)*, pp. 83-98.

Gardner, C. M. K., Laryea, K. B. & Unger, P. W. (1999). Soil Physical Constraints To Plant Growth and Crop Production, 106.

García-Orenes, F., Guerrero, C., Roldán, A., Mataix-Solera, J., Cerdà, A., Campoy, M., Zornoza, R., Bárcenas, G. & Caravaca, F. (2010). Soil microbial biomass and activity under different agricultural management systems in a semiarid Mediterranean agroecosystem. *Soil and Tillage Research*, *109*, pp. 110–115.

Gasmo, J., Hritzuk, K. J., Rahardjo, H., and Leong, E. C. (1999). In-strumentation of an unsaturated residual soil slope. *GeotechnicalTesting Journal*, *22*(2), pp. 128–137

Gatmiri, B., Delage, P. & Cerrolaza, M. (1998). A powerful finite element software for the analysis of unsaturated porous media. *Advances in Engineering Software*, *29*(1), pp. 29–43.

Geiman, C. M. (2005). *Stabilization of soft clay subgrades in Virginia phase I laboratory study*. Virginia Polytechnic Institute and State University: Master Thesis

Ghobadi, M. H., Abdilor, Y. & Babazadeh, R. (2014). Stabilization of clay soils using lime and effect of pH variations on shear strength parameters. *Bulletin of Engineering Geology and the Environment, 73(2)*, pp. 611-619.

Giménez-Morera, A., Sinoga, J. D. R. & Cerdà, A. (2010). The impact of cotton geotextiles on soil and water losses in Mediterranean rainfed agricultural land. *Land Degradation and Development*, *21*, pp. 210–217.

Gracindo, C. V., Louvandini, H., Riet-Correa, F., Barbosa-Ferreira, M. & Castro, M. B. (2014). Performance of sheep grazing in pastures of Brachiaria decumbens, Brachiaria brizantha, Panicum maximum and Andropogon gayanus with different protodioscin concentrations. *Trop. Anim. Health Prod*, *46*, pp. 733–737.

Grismer, M. E. & Hogan, M. P. (2005). Simulated rainfall evaluation of revegetation/ mulcherosion control in the Lake Tahoe Basin. soil treatment effect. *Land Degradation and Development*, *16*, pp. 489–501.

Grismer, M. (2012). Standards vary in studies using rainfall simulators to evaluate erosion. *Ca. Agri.*66(3), pp. 102–107.

Gofar, N. & Rahardjo, H. (2017). Saturated and unsaturated stability analysis of slope subjected. *Matec Web of Conferences, 101(5),* pp. 1-5.

Goh, S.G., Rahardjo, H. & Leong, E.C. (2010) Shear strength equations for unsaturated soil under drying and wetting. Journal of Geotechnical and Geoenvironmental Engineering*, 136(4),* pp. 594-606.

Gordon, V. J. (2012). Cause and Effect of Soil Acidity. *Publication Oklahoma State University*.

Guimaraes, R. M. L., Ball, B. C. & Tormena, C. A. (2011). Improvements in the visual evaluation of soil structure. *Soil Use & Management, 2,* pp. 395-403

Hardwick-Jones, R., Westra, S. & Sharma, A. (2010), Observed relationships between extreme sub-daily precipitation, surface temperatureand relative humidity,Geophys. Res. Lett.,37, L22805, doi:10.1029/2010GL045081.

Hamed, Y., J. Albergel, Y. Pépin, J. Asseline, S. Nasri, & P. Zante. (2002). Comparison between rainfall simulator erosion and observed reservoir sedimentation in an erosion-sensitive semiarid catchment. *Catena 50*, pp. 1-16.

Hassan, A. M. & Wolff, T. F. (1999). Search algorithm for minimum reliability index of earth slopes. *Journal of Geotechnical and Geoenvironmental Engineering, 125,* pp. 301–308

Haapala, T., Palonen, P., Korpela, A. & Ahokas, J. (2014). Feasibility of paper mulches in crop production: a review. Agric. *Food Sci. 23*, pp. 60–79.

Haynes, R. J. & Ludecke, T. E. (1981). Effect of lime and phosphorus applications on concentrations of available nutrients and on P, Al and Mn uptake by two pasture legumes in an acid soil. *Plant and Soil, 62(1)*, pp. 117–128.

Hector, A., Bazeley-White, E., Loreau, M., Otway, S. & Schmid, B. (2002). Overyielding in grassland communities: testing the sampling effect hypothesis with replicated biodiversity experiments. *Ecology Letters, 5(4)*, pp. 502–511.

Helle, T. E., Nordal, S., Aagaard, P. & Lied, O. K. (2016). Long-term effect of potassium chloride treatment on improving the soil behavior of highly sensitive clay Ulvensplitten , Norway, *422*, pp. 410–422.

Herbert, J. H. (1964). Effect of black and tranparent polythelene mulch soil temperature,sweet corn hrowth and maturity in an cool growing season. Natural mulches are not very effective for weed control in onions. *J. Am. Soc. Hortic. Sci., 86*, pp. 415–420.

Hettipathirana, T. D., Grey, N. A. & Naidu, R. (2004). Analysis of silicates using wavelength-dispersive x-ray fluorescence spectrometry, *X-ray Spectrometry, 33(2),* pp. 117-123.

Hsiao, C. F. C. (2012). Role of topography in the behavior of the matric suction of unsaturated fill slopes, pp. 61–69.

Hsu, S. & Guo, Y. (2005). Effect of Wind Speed on the Measurement of Rainfall, (Sevruk), *Crop, Environment & Bioinformatics*, pp. 81–86.

Hossain, M. K. (2010). Effect of rainfall on matric suction and stability of a residual granite soil slope. *Journal of Dhaka University of Engineering and Technology*, *1*(1).

Howes, J. & Campbell, J. (1953). Grass and its utilization in Trinidad. *Trop. Agric*, *30(3).*

Hölttä, T. & Sperry, J. (2012). Plant water transport and cavitation. *Proceedings of the NATO Advanced Research Workshop on Alternative Water Resources in Arid Area by Retrieving Water from Secondary Sources, Ein Bokek, Israel,* pp. 173-181

Homoya, M. A. (1994). Barren as Ecological Term: An Overview of Usage in the Scientific Literature. North American Conference on Savannas and Barrens.

Huang, C. C. & Yuin, S. C. (2010). Experimental investigation of rainfall criteria for shallow slope failures. *Geomorphology, 120(3-4)*. pp. 326-338.

Huat, B. B. K., Ali, F. H. J. & Low, T. H. (2006). Water infiltration characteristics of unsaturated soil slope and its effect on suction and stability, pp. 1293–1306.

Huat, B. B. K., Ali, F. H. & Abdullah, A. (2005). Response of suction, moisture and temperature of unsaturated granitic residual soil to rainfall”. *Electronic Journal of Geotechnical Engineering, 10.*

Humphry, J. B., Daniel, T. C., Edwards, D. R. & Sharpley, A. N. (2012). A portable rainfall simulator for plot-scale runoff studies. *Journal of Agricultural Safety and Health*, *18*(2), pp. 199–204.

Hughes, P., Glendinning, S. & Mendes, J. (2007) Construction Testing and Instrumentation of an Infrastructure Testing Embankment. Proceedings Expert Symposium on Climate Change: Modelling, Impacts & Adaptations (eds. Liong, S.Y., Phoon, K.K. and Toll, D.G.), Singapore: Research Publishing Services, pp. 159-166.

Husson, O., Charpentier, H., Razanamparany, C., Moussa, N., Michellon, R., Naudin, K., Razafintsalama, H., Rakotoarinivo, C. & Rakotondramanana, Séguy, L. (2008). Brachiaria sp., B. ruziziensis, B. brizantha, B. decumbens, B. humidicola. CIRAD, Manual Practice Manual at Madagascar, Vol. III, chap. 3, par. 4.

Ibgiez, S. & Calvo, A. (1997). Design and operation of a small and portable rainfall simulator for rugged terrain, *3630*, pp. 163–170.

Ikovi, G. O. D. (2009). The influence of the grain-size distribution and soil structure on the unsaturated shear strength of loess sediments in Belgrade , central Serbia, pp. 83–91.

Ismail, M. A. M., Hamzah, H., Soon, M. Ng., Abidin, Z., Hazreek, M., Azhar, A. T. S. & Madun, A. (2018). Analysis of Infiltration-Suction Response in Unsaturated Residual Soil Slope in Gelugor, Penang. *Journal of Physics: Conference Series*, *995*

Ishak, M. F., Sulaiman, F. F., Ali, N. & Kassim, A. (2016). Tree Water Uptake And Suction Distribution On Tropical Residual Soil Slope. *IOP Conference Series: Earth and Environmental Science*, *30*, pp. 12009.

Jamil, N., Aziman, M., Azhar, A. T. S. & Embong Z. (2015). Electrokinetic Remediation Assisted Phytoremediation to Remediate Barren Acidic Soil

Jeff, B. (1991). Soil and Water Relationships, The Samuel Roberts Noble Foundation, Inc. pp. 40–42.

Jeong, S., Lee, K., Kim, J. & Kim, Y. (2017). Analysis of Rainfall-Induced Landslide on Unsaturated Soil Slopes, pp. 1–20. https://doi.org/10.3390/su9071280

Jian, G., Liang, H., Huang, P., Na, T., Xue, L. & Guanghua, Y. (2016). FTIR and ESEM Analysis of soil moisture Microscopic conservation feature with liquid membrane. *MATEC Web of Conferences. 61.*

Jiang, Y., Chen, W., Wang, G., Sun, G. & Zhang, F. (2016). Influence of initial dry density and water content on the soil–water characteristic curve and suction stress of a reconstituted loess soil. *Bulletin of Engineering Geology and the Environment*, pp.1–11.

Jing, X., Chen, Y., Pan, C., Yin, T., Wang, W., Fan, X. (2019). Erosion Failure of a Soil Slope by Heavy Rain: Laboratory Investigation and Modified GA Model of Soil Slope Failure. *Int. J. Environ. Res. Public Health, 16(6)*, pp. 1075.

Jinyu, L., Qing, Y. & Maotian, L. (2010). Limit Equilibrium Analysis of the Influence of Matric Suction on Unsaturated Soil Slope Stability Engineering.

Johansson, J. (2014). *Impact of Water-Level Variations on Slope Stability*.

Jones, M. B., Jongen, M. & Doyle, T. (1996). Effects of elevated carbon dioxide concentrations on agricultural grassland production. *Agri and for Meteor, 79(4)*, pp. 243-252

Jones, E. W. (2006). Modelling the behaviour of unsaturated , saline clay for geotechnical design, pp. 1–6.

Jordán, A., Zavala, L. M. & Gil, J. (2010). Effects of mulching on physical properties and runoff under semi-arid conditions in southern Spain. *Catena 81*, pp. 77–85.

Jung, J. & Jang, J. (2016). Soil water characteristic curve of sediments containing a polyacrylamide solution. *Ge´otech Lett, 6(1)*, pp. 89–94.

Kader, M. A., Senge, M., Mojid, M. A. & Ito, K. (2017). Research Recent advances in mulching materials and methods for modifying soil environment. *Soil & Tillage Research*, *168*, pp. 155–166.

Kayyal, M. K. & Wright, S. G. (1991). Investigation of Long-Term Strength Properties of Paris and Beaumont Clays in Earth Embankments, Center for Transportation Research, University of Texas at Austin, Austin, pp. 134.

Keesstra, S., Pereira, P., Novara, A., Brevik, E.C., Azorin-Molina, C., Parras-Alcántara, L., Jordán, A. & Cerdà, A. (2016). Effects of soil management techniques on soil water erosion in apricot orchards. *Sci. Total Environ., 551*, pp. 357–366.

Krahn, J. & Fredlund, D. G. (1972) On total, matric and osmotic suction. *Soil Science, 115(5)*. pp.339- 348.

Kian, O. C., Ali, N., Kasim, F. & Ishak, M. F. (2016). Field Monitoring of Suction Distribution Due to Grass Cover, *International Journal of Engineering Innovation & Research*, *5*(6), pp.377–383.

Khoury, N. N., Zaman, M. M., Nevels, J. B. & Mann, J. (2003). Effect of Soil Suction on Resilient Modulus of Subgrade Soil Using Filter Paper Technique. *82nd Annual Meeting of the Transportation Research Board*, Washington, D.C.

Krahn, J., Fredlund, D. G. & Klassen, M. J. (1989). Effect of soil suction on slope stability at Notch Hill. *J. Can. Geotech, 26,* pp. 269- 278.

Kochian, K. V. (1995). Cellular mechanisms of aluminium toxicity and resistance in plant. *Annu. Rev. Plant Physiol. Mol. Biol.,* 46, pp. 237-260.

Kocurek, G. & Hunter, R. E. (1986). Origin of polygonal fractures in sand, uppermost Navajo and Page sandstones, Page, Arizona. *Journal of Sedimentary Research, 56(6).*

Koevoets, I. T., Venema, J. H., Elzenga, J. T. M. & Testerink, C. (2016). Roots Withstanding their Environment : Exploiting Root System Architecture Responses to Abiotic Stress to Improve Crop Tolerance, pp. 1–19.

Kondo, J., Saigusa, N. & Sato, T.(1989). A Parameterization of Evaporation from the Bare Soil Surface. *Journal of Applied Meteorology, 29*(5), pp. 385-389

Lal, R. (1974). Soil temperature, soil moisture and maize yield from mulched and unmulched tropical soils. *Plant Soil*, *40,* pp. 129–143.

Larney, F. J. & Angers, D. A. (2012). The role of organic amendments in soil reclamation : A review.

Lee, L. M., Kassim, A. & Gofar, N. (2011). Performances of two instrumented laboratory models for the study of rainfall infiltration into unsaturated soils. *Engineering Geology*, *117(1–2),* pp. 78–89.

Leong, E. C., Tripathy, S. & Rahardjo, H. (2003). Total suction measurement of unsaturated soils with a device using the chilled-mirror dew-point technique. *Géotechnique 53(2)*, pp. 173-182.

Leung, A. K., Garg, A., Coo, J. L., Ng, C. W. W. & Hau, B. C. H. (2015). Effects of the roots of Cynodon dactylon and Schefflera heptaphyllaon water infiltration rateand soil hydraulic conductivity. *Hydrological Processes*, *29*(15), pp. 3342–3354.

Leung, A., Garg, A. & Ng, C.W.W. (2015). Effects of plant roots on soil-water retention and induced suction in vegetated soil. Engineering Geology. 193. 183-197. 10.1016/j.enggeo.2015.04.017.

Leung, A. K., Sun, H. W., Millis, S. W., Pappin, J.W., Ng, C. W. W. & Wong, H. N. (2011). Field monitoring of an unsaturated saprolitic hillslope. *Canadian Geotechnical Journal, 48*(3), pp. 339-353

Leng, R.A. (1990). *Research Priorities for Cattle and Sheep Production in Venezuela*. University of New England: Armidale, Australia.

Lehmann, J. & Schroth, G. (2003). Nutrient Leaching, pp. 151–166.

Li, D., Tan, X. H., Hu, N., Shen, M. F. & Hou, X. L. (2012). Influence of rainfall infiltration on the reliability of expansive soil slopes. *Proc. of the 5th Asian-Pacific Symposium on Structural Reliability and its applications,* pp. 469-475.

Li, K. S. & Lumb, P. (1987). Probabilistic design of slopes. *Canadian Geotechnical Journal, 24*, pp. 520–535.

Li, X. Y. (2003). Gravel–sand mulch for soil and water conservation in the semiarid loess region of northwest China. *Catena*, *52(2),* pp. 105-127.

Li, A. G., Yue, Z. Q., Tham, L. G., Lee, C. F. & Law, K. T. (2005). Field-monitored variations of soil moisture and matric suction in a saprolite slope, *Geotechnical and Geosynthetics Engineering, 26*, pp. 13–26.

Li, S. X., Wang, Z. H., Li, S. Q., Gao, Y. J. & Tian, X. H. (2013). Effect of plastic sheet mulch, wheat straw mulch, and maize growth on water loss by evaporation in dryland areas of China. *Agric. Water Manag. 116,* pp. 39–49

Liang, C., Chai, Q., Lemke, R. L., Campbell, C. A., Zentner, R. P. & Gan, Y. (2014). Improving farming practices reduces the carbon footprint of spring wheat production. *Nature Communications*, pp. 1–13.

Lim, T. T., Rahardjo, H., Chang, M. F. & Fredlund, D. G. (1996). Effect of rainfall on matric suctions in a residual soil slope. *Canadian Geotechnical Journal*, *33(4),* pp. 618–628.

Liu, M. D. & Pemberton, S. (2010). A study of the strength of lime treated soft clays, pp. 245–251.

Little, D. N. (1999). Evaluation of Structural Properties of Lime stabilised soils and aggregates. *The national lime association, 1*.

Lu, N. & Likos, W. J. (2006). Suction Stress Characteristic Curve for Unsaturated Soil. *Journal of Geotechnical and Geoenvironmental Engineering*, *132*(5), pp. 591–602.

Lu, N. & Likos, W. J. (2004). Unsaturated Soil Mechanics, John Wiley & Sons,Inc.

Luk, S. H., Abrahams, A. D. & Parsons, A. J. (1993). Sediment sources and sediment transport by rill flow and interrill flow on a semi-arid piedmont slope, Southern Arizona. *Catena 20(1/2)*: pp. 93-111.

Lobet, G., Couvreur, V., Meunier, F., Javaux, M. & Draye, X. (2014). Plant water uptake in drying soils. *Plant physiology, 164(4),* pp. 1619-27.

Lora, M., Camporese, M. & Salandin, P. (2016). Design and performance of a nozzle-type rainfall simulator for landslide triggering experiments. *Catena*, *140,* pp. 77–89.

Low, B. K. & Tang, W. H. (2007). Efficient spreadsheet algorithm for first-order reliability method. *J. Eng. Mech. 133 (12),* pp. 1378–1387

Lourenc¸ S. D. N., Wang, G. H. & Kamai, T. (2015). Processes in model slopes made of mixtures of wettable and water repellent sand: implications for the initiation of debris flows in dry slopes. *Eng Geol*, *196*, pp. 47–58.

Macfarlane, D. & Shelton, H. M. (1986). Pastures in Vanuatu; Australian Centre for International Agricultural Research, Bruce, Australia.

Mackay, J. H. E. (1974). Register of Australian herbage plant cultivars. *J. Aust. Inst. Agric. Sci., 40,* pp. 91–93.

Malaya, C. & Sreedeep, S. (2012). Critical Review on the Parameters Influencing Soil-Water Characteristic Curve. *Journal of Irrigation and Drainage Engineering, ASCE, 138(1),* pp. 55–62.

Mariappan, S. (2016a). Soil suction and infiltration comparison between measured and computer prediction, (April).

Mariappan, S. (2016b). Rainfall Infiltration , Soil Matric Suction and Slope Engineering.

Marshall, T. J. (1958) A relation between hydraulic conductivity and size distribution of pores. *J Soil Sci., 9,* pp. 1–8.

Martínez-Mena, M., R. Abadía, V. Castillo, & J. Albaladejo. (2001). Experimental design using simulated rain for the study of changes in soil erosion during the storm. *Rev. C. & G. 15(1-2),* pp.31-43

Maffian, S., Huat, B. B. K. & Ghiasi, V. (2009). Evaluation on root theories and root strength properties in slope stability. *European Journal of Scientific Research 30(4)*, pp. 594-607.

Mavroulidou, M. & Gunn, M. (2015). Mechanical properties and behaviour of a partially saturated lime-treated,high plasticity. *Engineering Geology*, *193*, pp. 320–336.

Mazzacavallo, M. G. & Kulmatiski, A. (2015). Modelling water uptake provides a new perspective on grass and tree coexistence.

Martin, D., Beringer, J., Hutley, L. & McHugh, I. (2007). Carbon Cycling in a Mountain Ash Forest: Analysis of Below Ground Respiration. *Agricultural and Forest Meteorology, 147*, pp. 58–70.

Marschaner, H. (1995). Mineral Nutrition of Higher Plants, Academic Press, New York, NY, USA, 1995.

Makus, D. J., Tiwari, S. C., Pearson, H. A., Haywood, J. D. & Tirks, A. E. (1994) Okra introduction with pine straw mulch. *Agro forestry Sys. 27(2),* pp. 121-127

McCauley, A., Jones, C. & Jacobsen, J. (2005). Basic Soil Properties. *Soil and Water,* pp. 1–12.

McCauley, A., Jones, C. & Jacobsen, J. (2009). Nutrient Management. *Nutrient management module 9 Montana State University Extension Service. 4449*(9), pp.1–16.

McMillen, M. (2013). The Effect of Mulch Type and Thickness on the Soil Surface Evaporation Rate. California Polytechnic State University, USA.

Mcrae, K. B., Harnishs, J. B., Kolstee, H., Canada, A., Scotia, N. & Bol, C. (1993). Soil properties associated with formation of barren areas on formed dyke lands cropped to forage, pp. 527–538

Megahan, W. F., Wilson, M. & S. B. Monsen. (2001). Sediment production from granitic cutslopes on forest roads in Idaho, USA. Earth Surf. Process. *Landf. 26,* pp. 153–16

Mellouli, H. J., Hartmann, R., Gabriëls, D. & Cornelis, W. M. (1998). The use of olive mill effluents (margines) as soil conditioner mulch to reduce evaporation losses. *Soil and Tillage Research, 49(1)*, pp. 85-91.

Mitchell, J. K. & Soga, K. (2005). Fundamentals of soil behavior. Wiley, New York.

Miller, R.W. & D.T. Gardiner. (2001). Soils in our Environment. 9th Edn., Prentice Hall, Englewood Cliffs, New Jersey, pp. 671

Misra, R.K., Dexter, A.R. & Alston, A.M. (1986). Maximum axial and radial growth pressures of plant roots, *Plant and Soil, 95,* pp. 315-326.

Moreno, M. M. & Moreno, A. (2008). Effect of different biodegradable and polyethene mulches on soil properties and production in a tomato crop. *Sci. Hortic, 116*, pp. 256-263.

Moore, G. (2014). Saponins in Sub-Tropical Grasses in WA; Government of Western Australia: Perth, Australia, pp. 4.

Moore, G., Sanford, P. & Wiley, T. (2006). Signal Grass in Perennial Pastures for Western Australia; Department of Agriculture and Food Western Australia: Perth, Australia, pp. 2.

Morgan, R. P. C. (1986). Soil Erosion and Conservation. *Longman, New York*. pp. 298.

Morris, P. H., Graham, J. & Williams, D. J. (1992). Cracking in drying soils. *Canadian Geotechnical Journal, 29(2)*, pp. 263-277.

Moriwaki H., Inokuchi T., Hattanji T., Sassa K., Ochiai H. && Wang G. (2004). Failure processes in a full-scale landslide experiment using a rainfall simulator Landslides. pp. 277-288.

Mulumba, L. N. & Lal, R. (2008). Mulching effects on selected soil physical properties. *Soil Tillage Res. 98,* pp. 106–111.

Muntohar, A. S. (2015). Influence of the Soil-Water Retention Curve Models on the Stability of Residuals Soils Slope. *The 10th Indonesian Geotechnical Conference and the 19th Annual Scientific Meeting.* Jakarta. pp. 237-244.

Mutetwa, M. & Mtaita, T. (2014). Effects of mulching and fertilizer sources on growth and yield of onion. *J. Glob. Innov. Agric. Soc. Sci. 2,* pp.102–106.

Mwango, S. B., Msanya, B. M., Mtakwa, P. W., Kimaro, D. N., Deckers, J. & Poesen, J. (2016). Effectiveness of mulching under miraba in controlling soil erosion, fertility restoration and crop yield in the Usambara mountains, *Tanzania. Land Degrad. Dev. 27*,pp. 1266–1275.

Nam, S., Gutierrez, M., Diplas, P., Petrie, J., Wayllace, A., Lu, N. & Munoz, J. J. (2010) Comparison of testing techniques and models for establishing the SWCC if rivebank soil. *Engineering Geology, 110 (1-2),* pp. 1-10.

Neff, E. L. (1979). Why rainfall simulation? *In Proceedings of Rainfall Simulator Workshop, Tucson, Az. 10*, pp. 3-7

Ng, C. W. W. & Pang, Y.W. (2000). Influence of stress state on soil-water characteristics and slope stability. *Journal of Geotechnical and Geoenvironmental Engineering, 126(2)*, pp. 157-166.

Ng, C. W. W. & Zhan, L. T. (2007). Comparative study of rainfall infiltration into a bare and a grassed unsaturated expansive soil slope. *Soils and foundations, 47(2)*, pp. 207-217.

Ng, C. W. W. & Menzies, B. (2007). *Advanced unsaturated soil mechanics and engineering*.

Ng, C. W. W., Springman, S. M. & Alonso, E. E. (2009). Monitoring the performance of unsaturated soil slopes. *Laboratory and Field Testing of Unsaturated Soils*, pp. 187–204.

Ng, C. W. W., Woon, K. X., Leung, A. K. & Chu, L. M. (2012) Experimental investigation of induced suction distributions in a grass-covered soil. *Ecol. Eng*.

Ng, C.W.W., Woon, K.X., Leung, A.K. & Chu, L.M. (2013). Experimental investi-gation of induced suction distribution in a grass-covered soil. *Ecological Engineering,52,* pp. 219–223. doi:10.1016/j.ecoleng.2012.11.013.

Ng, C. W. W., Leung, A. K. & Woon, K. X. (2014). Effects of soil density on grass-induced suction distributions in compacted soil subjected to rainfall. *Canadian Geotechnical Journal,51(3),* pp. 311–321

Ng, C. W. W., Garg, A., Leung, A. K. & Hau, B. C. H. (2016a). Relationships between leaf and root area indices and soil suction induced during drying-wetting cycles. *Ecological Engineering,91,* pp. 113–118.

Ng, C. W. W., Ni, J. J., Leung, A. K., Zhou, C. & Wang, Z. J. (2016b). Effects of planting density on tree growth and induced soil suction. *Géotechnique,66,* pp. 711–724. doi:10.1680/jgeot.15.P.196.

Ng, C. W. W., Kamchoom, V. & Leung, A. K. (2016c). Centrifuge modelling of theeffects of root geometry on transpiration-induced suction and stability of vegetated slopes. *Landslides,13,* pp. 925–938

Ng, C. W. W., Wang, Z. J., Leung, A. K. & Ni. J. J. (2018). A study on effects of leaf and root characteristics on plant root water uptake, *Géotechnique, 69(2),* pp. 151-157

Ni, J., Anthony, L., Ng, C.W.W. & Pui, S. S. (2016). Investigation of plant growth and transpiration-induced matric suction under mixed grass-tree conditions. *Canadian Geotechnical Journal. 54*. 10.1139/cgj-2016-0226.

Nimmo, J. R., Schmidt, K. M., Perkins, K. S. & Stock, J. D. (2009). Rapid Measurement of Field-Saturated Hydraulic Conductivity for Areal Characterization. *Vadose Zone Journal*, *8*(1), pp. 142.

Nimmo, J. R. (2005) Unsaturated zone flow processes. In: Anderson MG and Bear J (eds.) *Encyclopedia of Hydrological Sciences, vol. 4,* pp. 2299–2322.

Ning, C. G. & Hu, T. G. (1990). The role of straw covering in crop production and soil management. *Better crops Int. 6,*pp. 6-7

Norashira, J., Zaidi, E., Aziman, M. & Azhar, A. T. S. (2016). Observation of pH Value in Electrokinetic Remediation using various electrolyte ($MgSO_4$, KH_2PO_4 and $Na(NO_3)$) for Barren Acidic Soil at Ayer Hitam, Johor, Malaysia

Nuth, M. (2008). Effective stress concept in unsaturated soils. *International Journal for Numerical and Analytical Methods in Geomechanics*, *32*, pp. 189–213.

Ochiai, H., Associaion, T., Forestry, T. S., Products, F., Sassa, K., Consortium, I. & Sammori, T. (2004). A fluidized landslide on a natural slope by artificial rainfall.

Ogundare, S. K., Babatunde, I. J. & Etukudo, O. O. (2015). Response of tomato variety (Roma F) yield to different mulching materials and staking in Kabba Kogi State. Niger. *J. Agric. Stud. 3*, pp. 61–70.

Oh, W. T. & Vanapalli, S. K. (2010). Influence of rain infiltration on the stability of compacted soil slopes. *Computers and Geotechnics*, *37*, pp. 649–657

Olasantan, F. O. (1999). Effect of time of mulching on soil temperature and moisture regime and emergence growth and yield of white yam in western Nigeria. *Soil Tillage Res. 50*, pp. 215–221

Ong, T. H. (2003). Rainfall-induced slope failures controlling factorsand mitigation with capillary barriers, Master Thesis, NanyangTechnological Institute, Singapore.

Osman, N., Saifuddin, M. & Halim, A. (2014). Contribution of Vegetation to Alleviate Slope ' s Erosion and Acidity. *Environmental Risk Assessment of Soil Contamination*, pp. 519–545.

Pal, A. & Pandey, S. (2017). Role of Arbuscular Mycorrhizal Fungi on Plant Growth and Reclamation of Barren Soil with Wheat (Triticum aestivum L .) crop. *Int. J. Soil Sci., 12*, pp. 25-31.

Pan, H., Qing, Y. & Pei-yong, L. (2010). Direct and Indirect Measurement of Soil Suction in the Laboratory.

Park, M. C. (2016). Behavior analysis by model slope experiment of artificial rainfall. *Natural Hazards and Earth System Sciences*, *16*(3), pp. 789–800.

Parsons, A. J., Abrahams, A. D. & Luk, S. H. (1990). Hydraulics of interrill overland flow on a semi-arid hillslope, southern Arizona. *Journal of Hydrology 177*(3-4), pp. 255-273.

Parsakhoo, A., Lotfalian, M., Kavian, A. & Hoseini, S. A. (2012). Calibration of a portable single nozzle rainfall simulator for soil erodibility study in hyrcanian forests, *7*(27), pp. 3957–3963.

Paul, K. I., Black, A.S. & Conyers, M. K. (2003). Development of acidic subsurface layers of soil under various management systems. *Advances in Agronomy*. *78,* pp. 187 -214.

Personne, E., Perrier, A. & Tuzet, A. (2003). Simulating water uptake in the root zone with a microscopic-scale model of root extraction. *Agronomie*, *EDP Sciences,23*(2), pp.153-168.

Pimentel, D. (2006). Soil erosion : A food and environmental threat, pp. 119–137.

Pizarro, R. & Link, O. (2010). A rainfall simulator for the in situ study of superficial, *70*, pp. 178–182.

Pollen-Bankhead, N. & Simon, A. (2010). Hydrologic and hydraulic effects of riparian root networks on streambank stability is mechanical root-reinforcement the whole story. *Geomorphology, 116(3-4),* pp. 353-362.

Pramusandi, S., Rifa, A. & Suryolelono, K. B. (2015). Determination of unsaturated soil properties and slope deformation analysis due to the effect of varies rainfall, *125*, pp.376–382.

Prats, S. A., Santons Martins, M. A., Malvar, M. C., Ben-Hur, M. & Keizer, J. J. (2014). Polyacrylamide application versus forest residue mulching for reducing post-fire runoff and soil erosion. *Sci. Total Environ. 468*, pp. 464–474.

Prats, S. A., Malvar, M. C., Vieira, D. C. S., MacDonald, L. & Keizer, J. J. (2016). Effectiveness of hydromulching to reduce runoff and erosion in a recently burnt pine plantation in central Portugal. *Land Degrad. Dev. 27*, pp. 1319–1333.

Prosdocimi, M., Jordán, A., Tarolli, P., Keesstra, S., Novara, A. & Cerdà, A. (2016). The immediate effectiveness of barley straw mulch in reducing soil erodibility and surface runoff generation in Mediterranean vineyards. *Sci. Total Environ. 547*, pp. 323–330.

Prosdocimi, M., Cerdà, A. & Tarolli, P. (2016). Soil water erosion on Mediterranean vineyards. *Catena 141*, pp. 1–21.

Powlson, D.S., Gregory, P.J., Whalley, W.R., Quinton, J.N., Hopkins, D.W., Whitmore, A.P., Hirsch, P.R. & Goulding, K.W.T. (2011). Soil management in relation to sustainable agriculture and ecosystem services. *Food Policy 36*, pp. 72–87

Puppala, A. J., Wattanasanticharoen, E. & Porbaha, A. (2006). Combined lime and polypropylene fiber stabilization for modification of expansive soils.

Qi, C., Qi, J., Li, L. & Liu, J. (2018). Stability Analysis Method for Rock Slope with an Irregular Shear Plane Based on Interface Model.

Qin, J., Hu, F., Zhang, B., Wei, Z. & Li, H. (2006). Role of straw mulching in non-continuously flooded rice cultivation. *Agric. Water Manag. 83*, pp. 252–260.

Qiu, Z. C., Wang, M., Lai, W. L., He, F. H. & Chen, Z. H. (2011). Plant growth and nutrient removal in constructed monoculture and mixed wetlands related to stubble attributes. *Hydrobiologia, 661(1),* pp. 251-260

Rahardjo, H. & Fredlund, D. G. (1995). Procedures for slope stability analyses involving unsaturated soils. Asian Institute of Technology, Lecture Series on Slope Failures and Remedial Measures, Bangkok, Thailand

Rahardjo, H., Santosa, V. A. & Leong, E. C. (2011). Numerical Analyses And Monitoring Performance of Residual Soil Slopes, *51*(3), pp. 471–482.

Rahardjo, H., Li, X. W., Toll, D. G. & Leong, E. C. (2001). The effect of antecedent rainfall on slope stability. *Geotechnical and Geological Engineering*, *19(3–4),* pp. 371–399.

Rahardjo, H., Nio, A. S., Leong, E. C. & Song, N. Y. (2010). Effects of Groundwater Table Position and Soil Properties on Stability of Slope during Rainfall. *Journal of Geotechnical and Geoenvironmental Engineering*, *136(11)*, pp. 1555–1564.

Rahardjo. H., Lee, T. T., Leong, E. C. & Rezaur. R. B. (2005). Response of a residual soil slope to rainfall. *Canadian Geothechnical Journal, 42*(2), pp. 34-35

Rahimi, A., Rahardjo, H. & Leong, E. C. (2011). Effect of antecedent rainfall patterns on rainfall-induced slope failure, *Journal of Geotechnical and Geoenvironmental Engineering*, *137(5),* pp. 483–491

Rahman, M. T. (2013). *Evaluation of Moisture , Suction Effects and Durability Performance of Lime Stabilized Clayey Subgrade Soils.* University of New Mexico: Master Thesis.

Rao, S. M. & Revanasiddappa, K. (2000a). Role of matric suction in collapse of compacted clay soil. *Journal of Geotechnical and Geoenvironmental Engineering*, *126*, pp. 85–90.

Rao, S. M. & Revanasiddappa. K. (2000b). Role of micro-structure in matrix suction of residual soils, Indian Institute of Science.

Ren, X., Jia, Z., Chen, X., Han, J. & Han, Q. (2007). Effect of ridge and furrow planting of rain- fall harvesting on soil available nutrient distribution and root growth of summer corn under simulated rainfall conditions. *Trans. Chin. Soc. Agric. Eng. 23*, pp. 94–99

Rees, H. W., Chow, T. L., Loro, P. J., Lavoie, J., Monteith, J. O. & , Blaauw, A. (2002). Hay mulching to reduce runoff and soil loss under intensive potato production in northwestern New Brunswick, Canada. *Can. J. Soil Sci. 82*, pp. 249–258.

Rezaur, R. B., Rahardjo, H., Leong, E. C. & Lee, T. T. (2003). Hydrologic Behavior of Residual Soil Slopes in Singapore, pp. 133–144.

Rice, R. C. (1975). Diurnal and seasonal soil water uptake and flux within a Bermuda grass root zone. *Soil Science Society of America Journal, 39(3)*, pp. 394-398.

Ridley, A. M. & Burland, J. B. (1993). A new instrument for the measurement of soil moisture suction. *Géotechnique*, *43*(2), pp. 321–324.

Riley, S. J. & Hancock, F. (1997). A rainfall simulator for hydrologic and erosion experiments on mines, with an example of its applications at Ranger Uranium Mine, Northern Territory, Australia. The Australasian Institute of Mining and Metallurgy Proceedings. 1, pp. 3-8.

Ries, J. B., Seeger, M., Iserloh, T., Wistorf, S. & Fister, W. (2009). Calibration of simulated rainfall characteristics for the study of soil erosion on agricultural land. *Soil & Tillage Research*, *106*, pp.109–116.

Ries, J. B., Iserloh, T., Seeger, M. & Gabriels, D. (2013). Rainfall simulations - constraints, needs and challenges for a future use in soil erosion research. Z. *Geomorphol. Suppl. 57(1)*, pp. 1–10

Robert, E. W. (2015). *Understanding vineyard soil*. second edition. Oxford University Press.

Robert, L. Z. (2015). *Lime: A Soil Amendment*. Six Chemicals That Changed Agriculture, pp. 41-54.

Robert, O. T. (1970). A review of pasture species in Fiji. *I. Grasses. Trop. Grassl*, 4, pp. 129.

Robichaud, P. R., Ashnum, L. E. & Sims, B. D. (2010). Posr-fire treatment effectiveness for hillslope stabilization.

Robichaud, P. R., Lewis, S. A., Wagenbrenner, J. W., Ashmun, L. E. & Brown, R. E. (2013). Postfire mulching for runoff and erosion mitigation. Part I: effectiveness at reducing hillslope erosion rates. *Catena 105*, pp. 75–92.

Romero, E. & Simms, P. H. (2008). Microstructure Investigation in Unsaturated Soils : A Review with Special Attention to Contribution of Mercury Intrusion Porosimetry and Environmental Scanning Electron Microscopy, pp. 705–727.

Rouillon, M. & Taylor, M. P. (2016). Can field portable X-ray fluorescence (pXRF) produce high quality data for application in environmental contamination research? *Environmental Pollution*, *214*, pp. 255-264.

Roose, T. & Fowler, A. C. (2004). A mathematical model for water and nutrient uptake by plant root systems. *Journal of theoretical biology, 228(2),* pp. 173-184.

Rosone, M., Farulla, C. A., Ferrari, A., Torta, C. & Celauro, C. (2016). Suction controlled drying and wetting cycle effects on the volumetric behaviour of a lime-treated high plasticity clay, *14020*, pp. 0–5.

Rogers, C. D. F. & Glendinning, S. (1996). Modification of clay soils using lime. In: Rogers, C. D. F., Glendinning, S., Dixon, N., editors. Lime stabilisation. London: Thomas Telford, pp. 99e114

Rosicky, M. A., Slavich, P., Sullivan, L. A. & Hughes, M. (2006). Surface and sub-surface salinity in and around acid sulfate soil scalds in the coastal floodplains of New South Wales, Australia, *Australian Journal of Soil Research, vol. 44,* pp. 17-25.

Rosicky, M. A., Sullivan, L. A., Slavich, P. G. & Hughes, M. (2004). Factors contributing to the acid sulfate soil scalding process in the coastal floodplains of New South Wales, Australia, *Australian Journal of Soil Research, vol. 42,* pp. 587-594

Russo, G. (2005). Water retention curves of lime stabilised soil. Advanced Experimental Unsaturated Soil Mechanics. Taylor & Francis, London, pp. 391–396.

Russo, G. & Vecchio, D. (2006.) Microstructure of a lime-stabilized sandy silt. Annual Meeting of Geotechnical Researchers 2006 - IARG 2006 Pisa, pp. 26-28

Sadeghi, S. H. R., Gholami, L., Homaee, M. & Darvishan, K. A. (2015). Reducing sediment concentration and soil loss using organic and inorganic amendments at plot scale. *Soil and Earth 6,* pp. 445–455.

Saifuddin, M. & Normaniza, O. (2016). Rooting characteristics of some tropical plants for slope protection. *Journal of Tropical Forest Science, 28(4),* pp. 469–478

Saroa, G. S. & Lal, R. (2003). Soil restorative effects of mulching on aggregation and carbon sequestration in a Miamian soil in Central Ohio. *Land Degrad. Dev. 14,* pp. 481–493.

Samantasinghar, S. (2014). *Geo-engineering properties of lime treated plastic soils.* National Institute of Technology Orissa, India: Master’s Thesis.

Schnellmann, R., Schneider, B. M. & Rahardjo, H. R. (2010). Effect of rising water table in an unsaturated slope. *Eng Geol, 114,* pp. 71–83.

Schoonover, J. E. & Crim, J. F. (2015). An Introduction to Soil Concepts and the Role of Soils in Watershed Management.

Shamshuddin, J. (1991). Laboratory Studies on the Release of Cations and Anions in Acid Sulf ate Soils, *14*(3), pp. 257–264.

Shamshudin, J. & E.A. Auxtero. (1991). Soil solution composition and mineralogy of some active acid acid sulfate soils in Malaysia as affected by laboratory incubation with lime. *Soil Sci. 152*, pp. 365-376.

Shamshuddin, J., Fauziah, C. I. & Sharifuddin, H. A. H. (1991). Effects of limestone and gypsum applications to a Malaysian Ultisol on soil solution composition and yields of maize and groundnut. *Plant and Soil. 134,* pp. 45-52.

Shamshuddin, J., Jamilah, I. Sharifuddin, H. A. H. & Bell, L. C. (1992). Changes in solid phase properties of acid soils as affected by limestone, gypsum, palm oil mill effluent and rock phosphate. *Pertanika,15*, pp. 105-114.

Shamshuddin, J., Sharifuddin, H. A. H. & Bell, L. C. (1998). Longevity of magnesium limestone applied to an Ultisol. *Commun. Soil Sci & Plant Anal. 29*, pp. 1299- 1313.

Shamshuddin, J. & Ismail, H. (1995). Reactions of ground magnesium limestone and gypsum in soil soils with variable-charge minerals. *Soil Sci. Am. J, 59,* pp. 106-112.

Shamshuddin, J., Azura, A. E., Shazana, M. A. R. S., Fauziah, C. I., Panhwar, Q. A. & Naher, U. A. (2014). Properties and management of acid sulfate soils in Southeast Asia for sustainable cultivation of rice, oil palm, and cocoa. *Advances in Agronomy , 124(1).*

Sherwood, P. (1993). Soil stabilization with cement and lime (state of the art review). London: Her Majesty Stationary Office.

Sheridan, G. J., Noske, P., Lane, P. & Sherwin, C. (2008). Using rainfall simulation and site measurements to predict annual interrill erodibility and phosphorus generation rates from unsealed forest roads: Validation against in-situ erosion measurements. *Catena, 73,* pp. 49-62.

Simon, A. & Collison, A. J. C. (2002). Quantifying the mechanical and hydrologic effects of riparian vegetation on streambank stability. *Earth Surface Processes and Landforms, 27,* pp. 527-546.

Slaton, N. A., Norman, R. J. & Gilmour, J.T. (2001). Oxidation rates of commercial elemental sulfur products to an alkaline silt loam from Arkansas. *Soil Science Society of America Journal. 65*, pp. 239-243. doi:10.2136/sssaj2001.651239x

Smalling, E. M. A. & Bouma, J. (1992). Bypass flow and leaching of nitrogen in a Kenyan Vertisol at the onset of growing season. *Soil Use Manage. 8,* pp. 44–48

Smets, T., Poesen, J. & Bochet, E. (2008). Impact of plot length on the effectiveness of different soil-surface covers in reducing runoff and soil loss bywater. *Prog. Phys. Geogr. 32,* pp. 654–677.

Smethurst, J. A., Briggs, K. M., Powrie, W., Ridley, A. & Butcher, D. J. E. (2015). Mechanical and hydrological impacts of tree removal on a clay fill railwayembankment. *Géotechnique, 65*(11), pp. 869–882

Sreedeep, S. & Singh, D. N. (2011). Critical review of the methodologies employed for soil suction measurement. *International Journal of Geomechanics, 11(2),* pp. 99-104

Stepniewski, W., Glinski, J. & Ball, B. C. (1994) Effects of compaction on soil aeration properties. *Soil compaction in crop production*, pp. 167-189

Stoltz, G., Cuisinier, O. & Masrouri, F. (2012). Multi-scale analysis of the swelling and shrinkage of a lime-treated expansive clayey soil. *Appl. Clay Sci. 61,* pp. 44–51.

Solé-benet, A. & Boer, M. M. (2001). Bio-physical assessment of the Tunisian oases. *Earth-Sci. Rev, 48,*pp. *39–70*

Sorbino, G. & Nicotera, M. V. (2013). Unsaturated soil mechanics in rainfall-induced flow landslides. *Eng Geol, 165,* pp. 105–132.

Sweeney, D. J. (1982). Some in Situ Suction Measurements in Hong Kong's Residual Soil Slopes. Proceedings of the 7th Southeast Asia Conference, Hong Kong, 1, pp. 91-106.

Tajudin, S. A. A., Abidin, M. H. Z., Madun, A. & Zawawi, M. H. (2016). Barren Acidic Soil Assessment using Seismic Refraction Survey. *Materials Science and Engineering, 136*pp. 291-315

Take, W. A. & Bolton, M. D. (2004). Discussion: Tensiometer saturation and the reliable measurement of soil suction. *Géotechnique*, *54*(3), pp. 229–232.

Tsai, T. L. & Chen, H. F. (2010). Effects of degree of saturation on shallow landslides triggered by rainfall. *Environ Earth Sci, 59,* pp. 1285–1295

Tan, J., Song, H., Zhang, H., Zhu, Q., Xing, Y. & Zhang, J. (2018). Numerical Investigation on Infiltration and Runoff in unsaturated soils with unsteady rainfall intensity. *Water,10,* pp. 914-925.

Tang, M., Xu, Q. & Huang, R. (2015). Site monitoring of suction and temporary pore water pressure in an ancient landslide in the Three Gorges reservoir area , China. *Environmental Earth Sciences*, pp. 5601–5609.

Tang, W. H., Yucemen, M. S. & Ang, A. H. S. (1976). Probability-based short term design of slopes. *Canadian Geotechnical Journal, 13,* pp. 201–215.

Tedesco, D.V. (2007). Hydro-Mechanical Behaviour of Lime-Stabilised Soils. University of Cassino, Italy: Ph.D Thesis

Terzaghi, K. & Peck, R. B. (1948). Soil Mechanics in Engineering Practice, John Wiley & Sons, N.Y.

Thurow, T. L., Blackburn W. H., Warren S. D. & Taylor C. A. (1987). Rainfall interception by midgrass, shortgrass and live oak mottes. *J. Range. Manage. 4,* pp. 455-460.

Trandafir, A. C. & Sidle, A. R. C. (2008). Monitored and simulated variations in matric suction during rainfall in a residual soil slope, pp. 951–961.

Toll, D. G., Rahardjo, H. & Leong, E.C. (1999). Landslides in Singapore. Proc. 2nd International Conference on Landslides, Slope Stability and the Safety of Infra-Structures, Singapore, pp. 269-276.

Vanapalli, S. K., Fredlund, D. G. & Pufahl, D. E. (1999) The influence of soilstructure and stress history on the soil-water characteristics of acompacted till. *Ge ́otechnique, 49*, pp. 143–159

Vanapalli, S. K. & Oh, W. T. (2012). Stability analysis of unsupported vertical trenches in unsaturated soils. I*n Proceeding of the GeoCongress,* pp. 2502-2511

Vanlauwe, B., Descheemaeker, K., Giller, K.E., Huising, J.,Merckx, R., Nziguheba, G.,Wendt, J. & Zingore, S. (2015). Integrated soil fertility management in sub-Saharan Africa: unravelling local adaptation. *Soil 1*, pp. 491–508.

Valencia, Y. (2013). Evaluation of soil matric suction , microstructure and its influence on collapsible behavior. *Advances in Unsaturated Soils*, pp. 329-341

Vepraskas, M. & Lindbo, D. L. (2012). Redoximorphic features as related to soil hydrology and hydric soils. *Wetlands, 19*, pp. 78–89.

Wang, S., Fu, B. J., Gao, G. Y., Yao, X. L. & Zhou, J. (2012). Soil moisture and evapotranspiration of different land cover types in the Loess Plateau , China, pp. 2883–2892.

Wang, Y., Cui, Y., Minh, A., Tang, C. & Benahmed, N. (2016a). Changes in thermal conductivity , suction and microstructure of a compacted lime-treated silty soil during curing. *Engineering Geology*, *202*, pp. 114–121.

Wang, X., Jiang, L., Yang, B., Nie, J. & Wang, J. (2016b). Impact of manure application on soil environment, rainfall use efficiency and crop biomass under dryland farming. *Sci. rep. 6.*

Wang, J., Huang, J., Zhao, X.,Wu, P., Horwath,W.R., Li, H., Jing, Z. & Chen, X. (2016c). Simulated study on effects of ground managements on soil water and available nutrients in jujube orchards. *Land Degrad. Dev. 27*, pp. 35–42.

Winter, W. (1976). Preliminary evaluation of twelve tropical grasses with legumes in northern Cape York Peninsula. *Trop. Grassl., 10*, pp.15–20.

Wilson, G. V., Dabney, S. M., McGregor, K. C. & Barkoll, B. D. (2004). Tillage and residue effects on runoff and erosion dynamics. *Transactions of ASAE, 47,* pp. 119–128.

Wilson, T. G., Cortis, C., Montaldo, N. & Albertson, J. D. (2014). Development and testing of a large, transportable rainfall simulator for plot-scale runoff and parameter estimation, pp. 4169–4183.

Wu, L. Z. & Selvadurai, A. P. S. (2016). Rainfall infiltration-induced groundwater table rise in an unsaturated porous medium. *Environmental Earth Sciences*, *75*(2), pp. 1–11.

Xiang, W. K. (2013). *Field and laboratory investigations of Bermuda grass induced suction and distribution*. Hong Kong University of Science and Technology: Ph.D Thesis.

Xu, B. & Low, B. K. (2006). Probabilistic Stability Analyses of Embankments Based on Finite-Element Method. *Journal of Geotechnical and Geoenvironmental Engineering*, *32*, pp. 1444–1454.

Yagi, N., Yatabe, R., Yokota, K. & Bhandary, N. P. (2000). Suction measurement for the predication of slope failure due to rainfall. Unsaturated soil for asia, pp. 847-851

Yan, C. R., He, W. Q. & Mei, X. R. (2010). Agricultural application of plastic films and its residue pollution prevention. *Science press Beijing, China.*

Yamoah, C., Ngong, N. M. C. & Dias, D. K. W. (1996). Reduction of P fertilizer requirement using lime and mucuna on high P-sorption soil of NW Cameroon. *African Crop Science Journal*, *4*, pp. 441–451.

Yang, R. R., Huang, W. H. & Tai, Y. T. (2005). Variation of resilient modulus with soil suction for compacted subgrade soils. *Journal of Transportation Research Board*, 1913, pp. 99–106.

Yu, B., Ciesiolka, C. A. & Langford, P. (2003). Calibration of an oscillating nozzle-type rainfall simulator. *Earth Surf Proc Landforms. 28*, pp. 1483- 1490.

Zhan, T. L. T., Ng, C. W. W. & Asce, M. (2004). Analytical Analysis of Rainfall Infiltration Mechanism in Unsaturated Soils, pp. 273–284.

Zhan, T. L. T., Ng, C. W. W. & Fredlund, D. G. (2006). Instrumentation of an Unsaturated Expansive Soil Slope, *30*(2), pp. 1–11.

Zhang, G., Qian, Y., Wang, Z. & Zhao, B. (2014). Analysis of Rainfall Infiltration Law in Unsaturated Soil Slope, pp. 1–8.

Zhang, S., Lövdahl, L., Grip, H., Tong, Y., Yang, X. & Wang, Q. (2009). Effects of mulching and catch cropping on soil temperature soil moisture and wheat yield on the Loess Plateau of China. *Soil Tillage Res. 102*, pp. 78–86.

Zhang, L. L., Zhang, J., Zhang, L. M. & Tang, W. H. (2011). Stability analysis of rainfallinduced slope failure: A review. *Proceedings of the Institution of Civil Engineers: Geotechnical Engineering*, *164*(5), pp. 299–316.

Zhang, L. L., Fredlund, D. G., Zhang, L. M. & Tang, W. H. (2004). Numerical study of soil conditions under which matric suction can be maintained. *Canadian Geotechnical Journal*, *41*(4), pp. 569-582.

Zhao, H., Wang, R.Y., Ma, B.L., Xiong, Y.C., Qiang, S.C. & Wang, C.L. (2014). Ridge-furrow with full plastic film mulching improves water use efficiency and tuber yields of potato in a semiarid rainfed ecosystem. *F. Crop. Res. 161*, pp. 137–148.

Zhao, Y., Li, Y., Zhang, L. & Wang, Q. (2016). Groundwater level prediction of landslide based on classification and regression tree. *Geodesy and Geodynamics*, *7*(5), pp. 348–355.

Zhou, A., Daichao, S., Scott, S. & Antonio, G. (2012). Interpretation of unsaturated soil behaviour in the stress - Saturation space, I: Volume change and water retention behaviour. *Computers and Geotechnics*, *43*. pp. 178-187.

Zou, J. (2015). *Assessment of the reactivity of expansive soil in Melbourne metropolitan area*. Civil, Environmental and Chemical Engineering, RMIT University: Master Thesis.