Jurnal
Teknologi

Full Paper

ANALYSIS OF SUCTION DISTRIBUTION RESPONSE TO RAINFALL EVENT AND TREE CANOPY

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Article history
Received
18 January 2016
Received in revised form
8 March 2016
Accepted
18 March 2016

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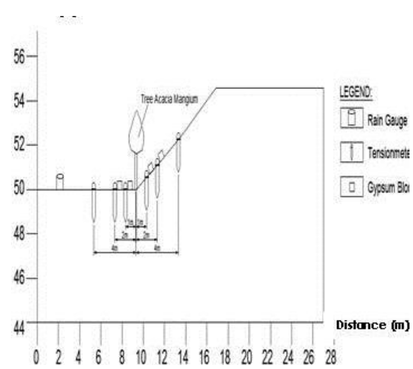
Graphical abstract



Abstract

This study provides an exploration of matric suction influenced by tree canopy interception on a single rainfall event. A field monitoring was carried out to measure matric suction at slope with two conditions; at toe of slope without tree and with a tree at toe of slope on a tropical residual soil. The variation in matric suction values and matric suction profiles response to the rainfall events on slope with and without a tree at toe were analysed to reveal the effect of the tree canopy. At initial condition, the matric suction was significantly higher at vicinity of tree compared to that of area without tree at toe of slope. However, a typical short and intense tropical rainfall has caused the matric suction to drop dramatically to a minimum value on slope without tree. This condition did not occur on slope with tree. Although, both slopes (with and without tree at toe) received the same amount of precipitation rainfall but the different responses in matric suction valueswere clearly shown at slope with tree at the slope toe. The short and intense rainfalls appeared to be the dominant factor to the suction variation at slope without tree, but not at slope with the tree. The tree canopy can be a factor to influence the suction variation at slope with tree as canopy interception reduced the amount of precipitation to the ground/sloping surface.

Keyword: Tree canopy; field monitoring; matric suction; suction distribution

Abstrak

Kajian ini menunjukan satu penerokaan dalam sedutan matrik yang dipengaruhi oleh kanopi pokok yang memintas sebahagian curahan hujan tunggal. Pemantauan lapangan dilakukan bagi mengukur sedutan matrik di cerun dalam dua keadaan; di kaki ceruntan papokok dan dengan pokok di kaki cerun pada tanah baki tropika. Perubahan dalam nilai sedutan matrik dan profil sedutan matrik yang terkesan daripada taburan hujan pada cerun dengan dan tanpa pokok di kaki cerun dianalisis bagi mendedahkan kesan kanopi pokok. Pada keadaan awal, sedutan matrik jauh lebih tinggi di persekitaran pokok berbanding tanpa pokok di kaki cerun. Walaubagaimanapun, hujan tropika biasa yang pendek dan lebat telah menyebabkan nilai sedutan matrik jatuh mendadak kepada nilai minimum di cerun tanpa pokok. Keadaan ini tidak berlaku di cerun dengan pokok. Walaupun, kedua-dua cerunini (dengan dan tanpa pokok di kaki) telahmenerimajumlahhujan yang sama tetapi perbezaan nilai sedutan matrik dapat dilihat dengan jelas terutamanya di cerun dengan pokok di kaki cerun. Hujan yang pendek dan lebat memainkan factor dominan kepada perubahan sedutan di ceruntan papokok tetapi tidak pada cerun dengan pokok. Kanopi pokok boleh menjadi faktor yang mempengaruhi perubahan sedutan di cerun dengan pokok bertindak sebagai bumbung pintasan yang mengurangkan jumlah curahan hujan terhadap permukaan/cerun tanah.

Kata kunci: Kanopi pokok;pemantauan lapangan;sedutan matrik;taburan sedutan

1.0 INTRODUCTION

Moststudiesof canopyrainfallinterceptionhavebeen conductedon field crops for agriculture and foresttrees related to planting for producing paper pulp,but very limited informationis availableontheeffectsof*accaciamagium*tree canopyon distributionofrainfallunder thecanopy particularly at slope [1]. According to [2], greater soilmatric suction valuesnearthetreetrunkand downto30 cmdepthcomparedto thatoutsidethetreecanopy. This wasdueto the tree canopy interception that reduced the rainfall precipitation to the ground/sloping soil surface.

Moisture content increases or suction of soil above the phreatic surface reduces when rainfall infiltrates into this zone, as the water flow or seepage downward can result in increase of the zone of the perched water table. The increase of perched water table area may lead to cause an instability to the slope, that has been proven by [3] and the failure may be induced by direct rainfall infiltration rather than by rising groundwater.

The cycle of hydrological condition of rainfall precipitation can be divided into several components, such as infiltration, evapotranspiration, runoff and interception (rainfall that is held by the vegetation). The amount of evapotranspiration can be negligible when categorizing rainfall components because it is only a small amount out of the total rainfall [3]. This generalizationresults in the estimate of rainfall as almost equal to the sum of the runoff and the infiltration.

There are many researchers have conducted studies on the response of suction distribution due to the single rainfall pattern on slope such as[4, 5, 6, 7 & 8], with further reducing the temporal interval in the observation. The key of their analysis is isolating rainfall patterns during monitoring period as several rainfall patterns were denoted byIntense rainfall and prolonged rainfall. In related to that, the suction distribution patterns for the slope at Faculty of Electrical Engineering, UniversitiTeknologi Malaysia were presented according to previous researchers with the additional of comparison with and without tree at the toe of the slope.

2.0 MATERIAL AND METHOD

A detailed and intensive ground investigation was conducted to characterize soil profile of the study area, especially to approximately identify the thickness and various distributionsof residual soils. The site investigation included trial pits, whichwere used to collect undisturbed samples and disturbed samples. The trial pitswere excavated using hydraulic back-hoe excavator, mounted on a tractor for ease of mobility as shown in Figure 1. The trial pitswere excavated at two locations, both at the toe of the slope. The procedure for the excavation of the trial pits was in accordance to[9]while the relevant laboratory tests were in accordance to [10]. The *in-situ* soil matric suction was measured using Jet-Fill tensiometer(Figures 2, 3 & 5) and gypsum moisture block (Figures 2, 3 & 4).The cross-sectional view of the field monitoring plot design,including rain gauge at Faculty of Electrical Engineering, UniversitiTeknologi Malaysia, is shown in Figure 6. Each equipmentis buried in the soil and it absorbs moisture from the soil or releases moisture into the soil, until its moisture content approaches equilibrium with the moisture content of the soil. The equipment measures the force which water is held in the soil by the soil particles. This force, referred to as soil suction, tension or potential, indicates how tightly the water is bound in the soil.

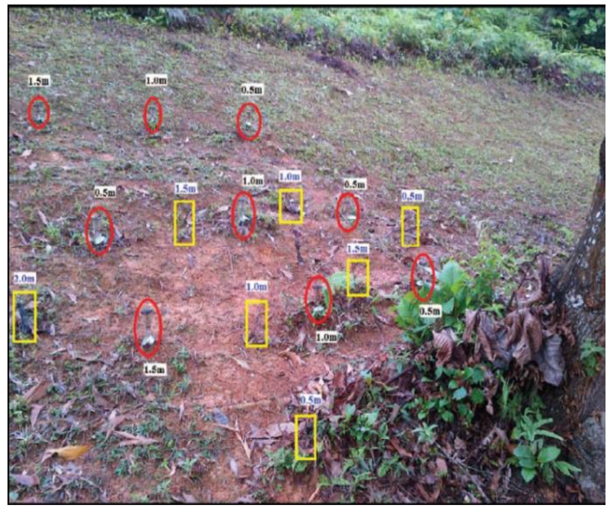


Figure 1 Jet-fill tensiometers and gypsum moisture blocks installed at slopingarea at several depths

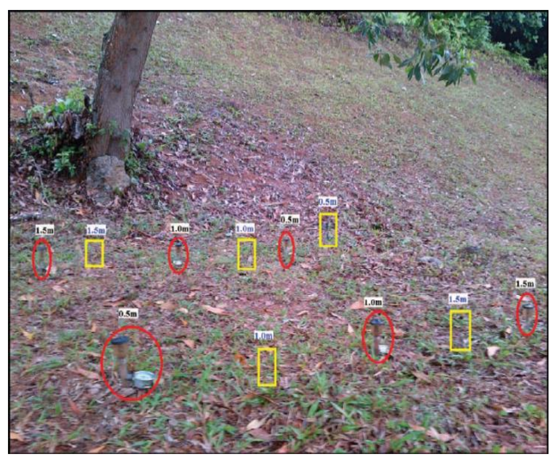


Figure 2 Jet-fill tensiometers and gypsum moisture blocks installed at flat areaat several depths

Figure 3 Gypsum block installed at the study area

Figure 4 Tensiometer installed at study area

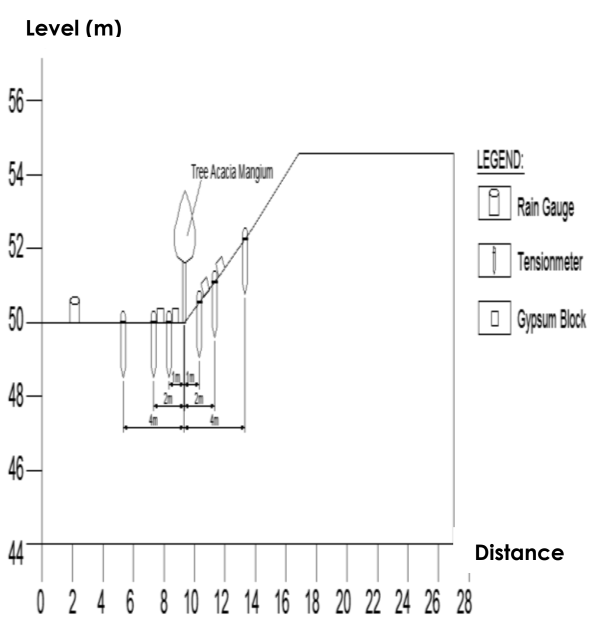


Figure 5 Cross-sectional view ofthe research plotdesign

3.0 RESULTS AND DISCUSSION

The disturbed and the undisturbed soilsampleswere collectedat theground surfaceand down to 1.5m depth. Series of laboratory testing were conducted to determinethe soil properties related to the soil types and the geotechnical properties. The results of the tests are presented in Table 1.

Themainphysicalindexpropertiesofthesoils have been investigatedforthis study area, suchasAtterberg limits, specific gravity, particlesizedistribution, porosity and void ratio.

Table 1 The properties of the soils in the study area

Composition	Sandy SILT
Gravel (%)	5.1
Sand (%)	20.9
Silt (%)	48.7
Clay (%)	25.3
Liquid Limit, LL (%)	71
Plastic Limit, PL (%)	39
Plasticity Index, PI (%)	32
Specific Gravity (G_s)	2.62
Void Ratio (*e*)	1.44
Porosity (*n*)	0.59
Permeability (k_{sat} (m/s))	4.1 x 10^{-7}
Effective Cohesion (c')	9
Effective Friction Angle (ϕ')	23
Unsaturated Friction Angle (ϕ^b)	20

The descriptions of rainfall pattern on intense rainfall occurred after prolonged dry period, was selected in this study. In July 2011 to August 2011, the slope without tree at study area experienced the driest condition throughout field monitoring study period, i.e. 11 days without any rainfall as shown in Figure 6. The highest suction recorded at depth 0.5m, 1.0m, 1.5m and 2.0mwere 46kPa, 47kPa, 49kPa and 52kPa, respectively. These results show that the maximum suction value of the soil is 52kPa, even during prolonged dry period. This limiting suction is approximately identical to the minimum suction corresponding to the residual water content of the in-situ residual soils, that suggested from previous studies [9,10,11,12,13,14,15]. However, a typical short and intense tropical rainfall that occurred on 4th August 2011 has caused the suction at 0.5m depth down to 2.0m to dropdramaticallyto a minimum value as shown in Figure 7.

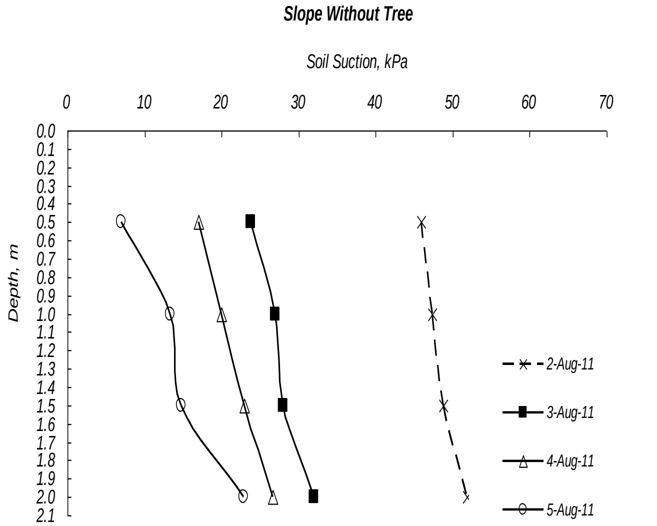


Figure 6 Matric suctionprofiles on slope without tree as a results of an intense and short rainfall

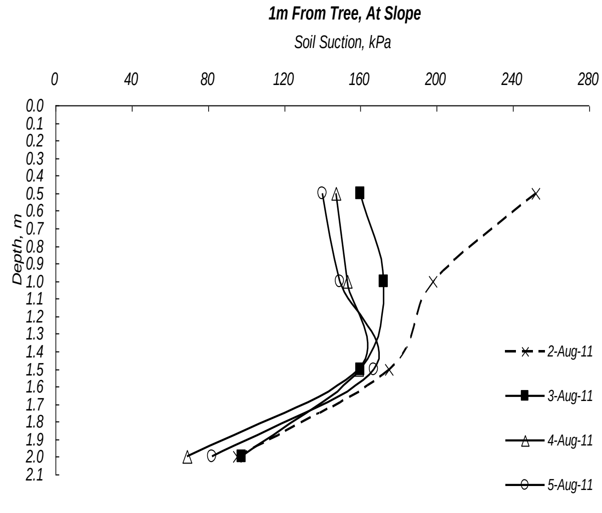


Figure 7 Matric suctionprofiles on slope 1m from tree as a result of an intense and short rainfall

Figure 6 shows plot of average suction with profiles at slope without tree,demonstrating that significant suction can develop during prolonged dry periods even though the suction has been readily dissipated with the occurrence of an intense and short rainfall event. The worst pore-water pressure conditions, however did not achieve positive pressures at all depths. The average suction profile with depth at slope without tree indicated significant suction has been readily dissipated with the occurrence of rainfall events (21mm/day) on 4thAugust 2011. The suction values at 0.5m, 1.0m, 1.5m and 2.0m depth dropped to the minimum value 6kPa, 13kPa, 15kPa and 23kPa, respectively.

The same condition occurred during this field monitoring study on slope with tree at the toe as shown in Figure 7. The intense rainfall which occurred after prolonged dry period, i.e., continuously 11 days without any rainfall, the highest matric suction recorded at 0.5m, 1.0m, 1.5m and 2.0m were 258kPa, 198kPa, 175kPa and 95kPa, respectively. The results show the maximum matric suction value of the soil is 258kPa. Subsequently, followed by intense rainfall event (21 mm/day), the suction dropped but did not reach the lowest value as matric suction on slope without tree (Figure 8). The matric suction at the depth of 0.5m dropped dramatically from 258kPa to 140kPa while it dropped gradually at depth of 1.0m from 198kPa to 153kPa. However, the matric suction at 1.5m and 2.0m depth remain unchanged. The suction at depth 0.5 m was sensitive to intense rainfall in comparison to 1.0m, while 1.5m and 2.0m were not affected. Although, both slopes (with and without tree at toe) received the same amount of precipitation rainfall but the difference response in matric suction value can be clearly shown at slope with tree at toe of the slope (Figure 9).

During the continuous daily rainfall 18th to 24th December 2011 for both slopes, due to the high intensity rainfalls, the suction was significantly reduced as shown in the plot of average suction with depth profiles (Figure 9). Throughout the combination of antecedent and intense rainfall, the lowest suction values at 0.5m and 1m were encountered on 20th December 2012 due to the highest rainfall amount (62 mm/day) on 19th December 2012. From the results, the lowest suction in the soil of both slopes at Faculty of Electrical Engineering occurred and itwas dominated by the rainfall intensity together with antecedent rainfall. The worst pore-water pressure conditions did not achieve saturated condition (0 kPa suction value) atalldepths. It can be concluded, the canopy interception was negligible due to the occurrence of antecedent and moderately intense amount of rainfall, which allow the total rainfall precipitation not being intercepted and thus to reach directly the soil surface under the tree canopy.

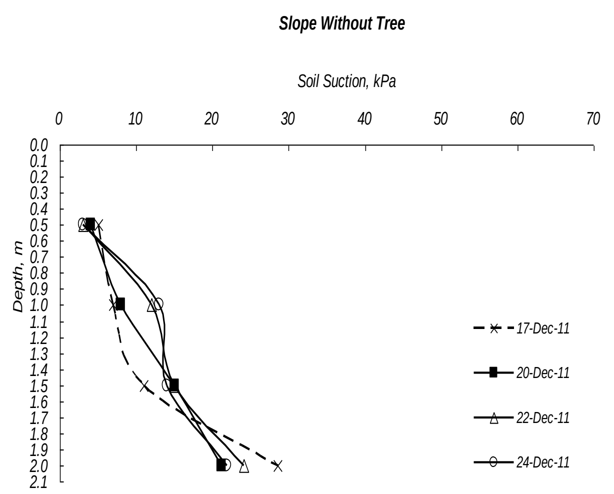


Figure 8 Matric suctionprofiles on slopewithout tree as a result of prolonged antecedentrainfall

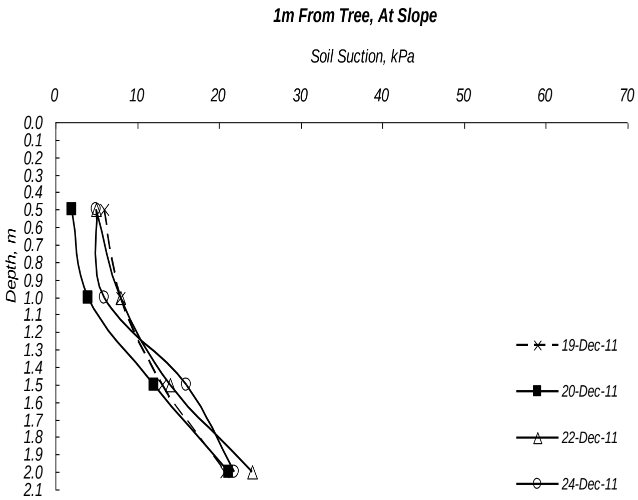


Figure9 Matric suctionprofiles on slope 1m from tree as aresult of prolonged antecedentrainfall

4.0 CONCLUSION

The responses of the suction distribution of two different rainfall patterns were analysedduring the monitoring at the slopes without and with tree at the toe, disclosed that the soil lost its suction quite frequently after experiencing a typical major and minor rainfall events. The short and intense rainfall and rainfall amount appear to be the dominant factors to the suction variation in slope without tree, but not slope with tree at the slope toe. The tree canopy can be a factor to influence the suction variation in slope with tree at toe as canopy interception in order to reduce amount of rainfall precipitationdirectly to the ground/sloping soil surface. However, the prolonged and antecedent rainfalls are the major dominant factors that brought down the suction variation to the lowest suction. The canopy interception was negligible by reason of intense rainfall amount has occurred which permitted the rainfall to directly reach and infiltrateground/sloping soil surfaceunder the tree.

Acknowledgement

The authors would like to thank the UniversitiTeknologi Malaysia and Universiti Malaysia Pahang for providing the necessary facilities to do the experimental works in this study.

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