TREE-INDUCED DEFORMATION IN UNSATURATED SOILS

MU'AZU MOHAMMED ABDULLAHI

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Civil Engineering)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

MAY 2011

I dedicated this thesis to my late father and beloved mother and my family for their support, encouragement and understanding.

ACKNOWLEDGEMENTS

I wish to express my deep and sincere gratitude to Dr. Nazri Bin Ali, my main supervisor and mentor during PhD study, for his helpful support, advices, constructive criticism, and critical review of the thesis. Thank you, Dr. Nazri! I was so happy working with you. Special appreciation is extended to my Co-supervisor Associate Professor Dr. Kamarudin Bin Hj Ahmad for his help, support, and helpful technical discussions. I would also like to thank Professor Dr. Shahrin Mohammad, Professor Dr. Khairul Anuar Kasim and Associate Professor Dr. Rosli Hainin, Dean Faculty of Civil Engineering, Deputy Dean Research and Post-graduate Studies, Faculty of Civil Engineering and Head of Department, Geotechnics and Transportation Engineering, Universiti Teknologi, Malaysia, respectively, for their guidance and feedback. I also appreciate Professor D.G. Fredlund and Professor S.W. Rees for their valuable help and guidance.

I would like to express my deep appreciation to my beloved late father Alhaji Mu'azu Abdullahi, who passed away on 3rd July, 2009. He sacrificed a lot to raise me and to support my education. I thank my devoted mother Malama Rabiat Mu'azu from the bottom of my heart for her prayers and encouragement. I will never forget my beloved wife Binta Hadi Jume for her help, support, prayer and encouragement. She was always there to help and support me anytime, anywhere. She sacrificed a lot to provide me comfort and a good study environment during this Ph.D study. My special appreciation is also extended to my little son Al-Amin Mohammed Mu'azu and my baby girl Faridah Mohammed Mu'azu. I forgot my troubles and found peace of mind when I'm playing with them.

Special thanks go to FUT, Minna for releasing and assisting me to pursuit my PhD. I also give thanks to Almighty Allah for giving me the opportunity to meet and study with these great people at UTM. I cherish my entire friends for their support in one way of the other.

ABSTRACT

Settlements of lightly loaded structures are frequently caused by changes in matric suction causing shrinkage or swelling of soils. These structures are often not designed to deal with influences of these changes. This study explores issues related to ground displacement due to changes in matric suctions induced by root water-uptake by tree. Numerical simulations of moisture migration patterns in the unsaturated zone and in the vicinity of established tree were performed. The moisture flow model used is based on Richard's equation with incorporated sink term and integrated with appropriate water-uptake models in 2*D* and 2*D* axi-symmetric form. The numerical solution was derived from a finite element approach for spatial discretisation along with a finite difference time-marching scheme. A series of numerical simulations have been performed by the model to assess functionality of stress-deformation analysis partially coupled to flow equation. The model is capable of estimating matric suction changes and accompanying volume change profiles due to water-uptake over a full-annual cycle. Time dependent boundary conditions based on rainfall data effects have also been explored. Results of sensitivity and parametric analyses shows that the predicted ground displacements are sensitive to all the parameters tested. On the other hand, all initial time step sizes used for testing the convergence criterion on the simulation works was found to converge and the simulated results shows difference of not more than ±5 %, which is considered satisfactory. The research also provides an assessment of the significance of trees induced suction changes on unsaturated soil slopes. The model is capable of estimating ground displacements due to matric suction changes on sloping ground. The magnitude of the ground displacement on the sloping surface depends on the relative position of trees on the slope. A relatively straight forward simple approach to model the matric suction changes and accompanying volume change profiles beneath tree as a result of water-uptake has been developed. The resulting model is potentially valuable for a range of geotechnical engineering problems situated on the vadose zones containing trees.

ABSTRAK

Enapan yang dialami struktur ringan selalunya disebabkan oleh sedutan matrik yang menyebabkan pengembangan dan pengecutan tanah. Pengaruh perubahan ini biasanya tidak diambilkira dalam rekabentuk struktur. Penyelidikan ini dilakukan untuk mengkaji isu yang berkaitan dengan pergerakan tanah disebabkan penyerapan air oleh tumbuh-tumbuhan. Simulasi berangka corak pergerakan lembapan dalam zon tak tepu dan kawasan berhampiran tumbuhan matang telah dilakukan. Model yang digunakan adalah berasaskan persamaan Richard yang digabungkan dengan '*sink term*' dan model penyerapan air yang sesuai dalam bentuk dua-dimensi dan dua dimensi paksi-simetri. Penyelesaian berangka dicapai menggunakan kaedah unsur terhingga untuk pemisahan ruang di samping kaedah unsur kebezaan bagi skima '*time marching*'. Satu siri simulasi berangka telah dijalankan untuk menilai fungsi analisis tegasan-ubahbentuk yang sebahagiannnya digandingkan dengan persamaan aliran. Model ini berupaya untuk menganggar perubahan sedutan matrik dan profil perubahan isipadu akibat dari pengambilan air oleh tumbuhan bagi satu kitaran lengkap setahun. Keadaan sempadan yang bergantung kepada masa dan data hujan juga dikaji. Keputusan analisis kepekaan dan parametrik menunjukkan pergerakan tanah yang diramal adalah peka terhadap semua parameter yang diuji. Kesemua saiz langkau masa awalan yang digunakan untuk menguji kriteria penumpuan simulasi menunjukkan perbezaan hasil simulasi kurang dari 5%, satu nilai yang memuaskan. Kajian ini juga memberikan penilaian terhadap kepentingan perubahan sedutan oleh tumbuhan di kawasan tanah lereng tak tepu. Di samping itu, model yang dibangunkan berkeupayaan menganggar enapan disebabkan perubahan sedutan matrik di kawasan bercerun. Magnitud anjakan tanah didapati bergantung kepada kedududukan relatif tumbuhan di sesuatu cerun. Satu pendekatan mudah ke arah permodelan perubahan sedutan matrik dan profil perubahan isipadu tanah yang berlaku di bawah tumbuhan akibat penyerapan air oleh tumbuhan tersebut juga telah dibangunkan. Model yang dihasilkan berpotensi untuk digunakan bagi menyelesaikan permasalahan berkaitan kejuruteraan-geoteknik yang terletak dalam zon vados yang terdapat tumbuhan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

$C(\psi)$	-	Specific moisture capacity
CI	-	Compression Index
C_r	-	Re-compression index
C_s	-	The swelling index
c_1^s	-	Coefficient of volume change solid phase
c_2^s	-	Coefficient of volume change solid phase
c_1^w	-	Coefficient of volume change of the water phase
c_2^w	-	Coefficient of volume change of the water phase
de	-	The change of void ratio in the element
E	-	Elasticity parameter
E_g	-	Gravitational potential energy
E_w	-	Water volumetric modulus
FE	-	Finite element
FD	-	Finite difference
g	-	Acceleration due to gravity = (9.81m/s^2)
G_j , g_j	-	Prescribe known functions or operators
h, h_p	-	Equivalent head of water
H	-	Elasticity parameter
H_w	-	Water volumetric modulus
i	-	Hydraulic gradient
IVR	-	Initial void ratio
K, K_s	-	Saturated hydraulic conductivity
$K(\phi)$,$K(\psi)$	-	Unsaturated hydraulic conductivity
K_0	-	Coefficient of earth pressure at rest
LWP	-	Leaf water potential

m	-	Mass
n	-	Porosity of soil
N_i, N_r, N_s	-	Shape function
OCR	-	Over consolidation ratio
PR	-	Poissons' ratio
R, R_Ω	-	The residual or error introduced by the approximation
r_{rj}, r_r	-	Maximum rooting radial distance
S_r	-	Degree of saturation
S	-	Matric suction
SWAT	-	Soil-Plant–Atmosphere
SMD	-	Soil moisture deficient
SWCC	-	Soil water characteristic curve
SWRC	-	Soil water retention curve
S_{max}	-	Sink term
$S(\psi)$	-	Sink term
$S(\psi,z,r)$	-	Sink term
$S(\psi,x, z)$	-	Sink term
$T, T_j T_p$	-	Potential transpiration rate
t	-	Time
UW	-	Unit weight
u	-	Functions in Ω
u_a	-	The pore-air pressure
u_w	-	The pore-water pressures
$\hat{u}$	-	The approximation to the function u
V_T	-	Total volume
V_w	-	Volume of water
V_v	-	Volume of void.
V, V_w	-	Volume of water
v_x, v_y, v_z	-	Velocity of water flow
W_1	-	The weighting functions
χ	-	Effective stress parameter
x, r, z	-	Cartesian co-ordinates
z_{rj}, z_r	-	Maximum rooting depth

$\alpha(\psi)$	-	Pressure head dependent reduction factor
σ_{ij}	-	Components of the total stress tensor
σ_m	-	Mean stress
σ_r	-	The horizontal stress
σ_z	-	Vertical net normal stress
δ_{ij}	-	Kronecker delta
ϵ_v	-	Volumetric strain.
α, l, m, n	-	Soil specific parameter
ΔV_a	-	Change volume of air
ΔVv	-	Change volume of void
ΔVw	-	Change volume of water
γ	-	Density
θ	-	Volumetric moisture content
θ_r	-	Residual water content
θ_s	-	Saturated water content
ρ, ρ_w	-	Density
σ	-	Total stress
π	-	Osmotic suction
μ	-	Poissons' ratio
σ'	-	Effective stress
ψ	-	Capillary potential
$\hat{\psi}$	-	The approximation to the ψ
$\hat{\phi}$	-	The approximation to the ϕ
Ω	-	Domain
Γ	-	Boundary
λ	-	Water flux at the boundary
∇	-	Divergent vector

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

Buildings and the environment are key elements of quality of life. Trees are an integral and critical part of urban landscapes providing important aesthetic and environmental contributions that makes towns and cities more pleasant, safer and healthier to live in. Many trees are situated close to structures; such as buildings, road pavements and footways. These trees give shelter from noise and wind, reduce chemical and particulate air pollution, provide shade and add value to nearby property (Building Research Establishment (BRE), 2004). Trees also benefit urban ecosystems, by sustaining biodiversity and in addition, they reduce storm water run-off and prevent soil erosion.

Justifiably, trees contribute so much to our environment however, trees and buildings in close proximity can lead to problems, either restricting light or causing damage due to their root activities and matric suction changes (BRE, 2004). These suction variations occur in the presence of tree and indeed also can occur on removal of tree. The planting of trees close to infrastructures needs to be planned and undertaken from a sound science based research (BRE, 2004). One the other hand, removal of city trees will lead to a decline in the quality of urban landscapes and large-scale felling of trees would not be acceptable to the public at large.

Structural damage is frequently associated with the close proximity of trees to especially low-rise buildings. Trees can extract water from below the foundations causing some particular clay sub-soils to shrink, ultimately leading to failure of the foundations and cracks in superstructure (BRE, 2004). It is known that trees add to the drying of soil at depth and only few geo-structures are design to deal with their influences. These suction changes have an important role in the analysis of a number of geotechnical engineering problems. Meanwhile, trees are becoming increasingly recognized as a vital factor causing a substantial moisture migration through evapotranspiration (Ali, 2007).

Cycles of shrinkage and swelling can also have significant effects on the properties and behavior of soils. The volume changes that result from both shrinkage and swelling of fine-grained soils are often large enough to cause damage to small buildings and highway pavements. Jones and Holtz (1973) estimated that shrinking and swelling soils caused about $2.3 billion in damages annually in the United States (US) alone. This is more than twice the annual cost from floods, hurricanes, tornadoes, and earthquakes combined together. A more recent estimate is about $9 billion in damages annually to buildings, roads, airports, pipelines and other facilities (Jones and Jones, 1987). Proper functionality of clay barriers may also be affected negatively by swelling or shrinkage. A clay barrier that has swollen may lose its integrity upon heaving, or it may shrink and crack later when the water is removed (Goldman, 1988).

In United Kingdom (UK) the cost of repairing the damage caused by the failure of domestic house foundations, due to subsidence, was in order of £300-£400 million annually (Building Research Establishment (BRE), 2004; BRE, 1999). Not all of this can be attributed to the presence of tree roots. However, most of the subsidence incidents in the UK are found to occur in areas with clay soils. In these areas, tree roots are claimed to have an effect on subsidence incidents in 73% of cases (Loss Prevention Council, 1995). Currently, no existing methods that would reliably predict which trees may cause damage and not all trees near buildings are implicated. Decreasing water uptake by trees may lessen subsidence risk by conserving soil moisture and reducing clay soil shrinkage (BRE, 2004).

The effect of stresses induced due to transpiration driven root water-uptake by vegetation was incorporated in the current research. It is worthwhile to investigate the safe distance between geotechnical structures in terms of L: H ratios. These can be used to predict soil movements and thereby improving the future designs of geotechnical structures. In the same vein, Geotechnical Engineers will be better informed on potential effects of trees in geotechnical structures.

Rees and Thomas (1991) explored experimental and numerical one-dimensional moisture transfer and volume change behavior of a partially saturated soil. The investigation constitutes a component of seasonal ground movement effects on buried services. A seasonal water variation as a result of root water-uptake was measured by Biddle (1998). This prompted a two-dimensional simulation of seasonal variation of moisture migration due to root water-uptake to be carried out by Rees and Ali (2006) which was in good agreement with the measured variation by Biddle (1998). A treatise moisture variation was carried out by Rees and Ali (2006) without coupling the effect of stresses induced as a result of vegetative moisture variation. This forms the basis of this current research; moisture variation as a result of root water-uptake was simulated and then partially coupled to stress-deformation to evaluate vertical ground displacements.

1.2 Problems Statement

Shallow seated geotechnical structures are often constructed on unsaturated soil and have to resist deformation associated with external loads as well as matric suction changes in the soils. Some of these types of structure are lightly loaded and therefore, displacements are mostly resulted from changes in matric suction. Moreover, they are often not designed to deal with influence of these matric suction changes. Changes in matric suction can occur as a result of variation in climatic conditions, depth of water table, water uptake by tree, removal of tree or infiltration as result of rainfall. Therefore, a predictive capability that will enable the extent and magnitude to which vegetation causes matric suction changes, ground displacements and how it affects geotechnical structure is clearly of great importance.

1.3 Aim and Objectives

The work is aimed at determining tree-induced deformation in unsaturated soils through the application of numerical techniques. In line with the major aim of the research, the following are the objectives the study:

1. To develop stress–deformation model for two-dimensional axi-symmetric water uptake processes associated with an established tree with finite element formulation.
2. To develop partial coupled 2-*D* axi-symmetric root water-uptake and stress-deformation analysis for unsaturated soil due to vegetative induced matric suction changes.
3. To verify and validate the proposed model using simulations results published in this area and comparison with site data respectively.
4. To demonstrate the effects of changing the soil types, trees and climatic parameters on the numerical predictions and assess and determine the key parameters that influence ground displacements due to root water uptake by tree.
5. To provide an assessment of the role of tree on slope settlement due to ground water-uptake by tree.

1.4 Scope and Limitations of the Research

The underlying principle of maintaining simple acceptable approach would be adopted. The research will be limited to:

i. Simulation of tree induced vertical ground displacements as a result of water-uptake within a vicinity of matured tree, so root growth are not to be considered.

ii. Two-dimensional axi-symmetric formulation and radial symmetry is assumed to exist, since a single isolated tree would be considered, with no adjacent trees within the vicinity. More complex behaviour will occur when adjacent trees interact.

iii. Non-deformable unsaturated flow would be considered and non-deformable soil fabrics exist with deformation due to change in pore water pressure only.

iv. The stress deformation would be partially coupled to the flow equation through appropriate theoretical formulation and FORTRAN subroutines.

v. Oxygen diffusion can only occur in a non-saturated soil, which is necessary for most root growth. Therefore, moisture flow in an unsaturated soil is considered.

vi. Unsaturated flow is described by a partial differential equation and shall be solve by numerical methods, finite element for spatial discretization and finite difference for time discretization shall be used.

vii. The temperature dependent flow parameters, which is second order partial differential equation are not considered, therefore isothermal conditions are assumed to exist.

viii. Field soil often exhibit heterogeneity, however, isotropic and homogenous conditions are assumed to exist throughout the depth of the soil profile.

ix. Grasses are not given separate attention, since tree use more water than most other types of tree.

x. In the current research, the primary interest is to relate the predicted matric suctions to ground displacements. The predicted matric suction variation as a result soil water-uptake by tree root is used as an input for stress-deformation analysis.

xi. Macroscopic approach for root water-uptake model was used.

xii. The model was verified and validated with field data from Canada, Australia and United Kingdom respectively.

1.5 Significance of Research

Many trees are located close to geotechnical structure such as foundation, earth dam, slopes, retaining wall, levees and structure such as building and road pavement. Trees influences the moisture migration in the soil, hence causes changes in matric suction. The ability to predict the influence of tree induced moisture movement which causes structural deformation as a result of shrinkage and/or heaving is a potentially important planning and management tools in geotechnical engineering design and analysis.

1.6 Framework of the Research

The research explored tree-induced deformation pattern in the unsaturated soils zone due tree root water-uptake. This study focuses on issues related to vertical ground displacements due to root water-uptake by plant. The numerical simulation of moisture migration patterns in the unsaturated zone as well as accompanying ground displacements within the vicinity of established tree was analyzed. The flow model is based on Richard's equation and Darcy's law of conservation of mass. The moisture flow model used is incorporated with sink term and integrated with appropriate water-uptake models; 2*D*, and 2*D* axi-symmetric form. A numerical solution was achieved by the finite element method for spatial discretisation along with a finite difference time-marching scheme for time discretization.

The current research required significant development and extension of this in-house FORTRAN code which was set-up for two-dimensional, cartesian flow problems to incorporate deformation and partial coupling of the water-uptake and the deformation. A stress-deformation formulation is included by adopting groundwater field concept with two stress state variables for unsaturated soils. The stress-deformation is partial coupled to 2-*D* axi-symmetric root water-uptake for unsaturated soil through the stress state variables and effective stress concept. At the start of this research programme an existing finite element solution of the Richard's equation for unsaturated soil was made available (Ali, 2007 and Rees and Ali, 2006).

1.7 Thesis Organization

An overview of related research work to the analysis of root water uptake, suction, effective stress and deformation in unsaturated soil is presented in Chapter 2. The review provides a commentary on the general significance of the water-uptake process. It then provides a summary of the key mechanisms involved and aims to provide some background information that can be utilized in subsequent simulation work. The review also summarizes developments in modelling the stress-deformation analysis.

The theoretical basis for describing moisture flow in an unsaturated soil is presented in Chapter 3. Some of the fundamental concepts used to describe moisture flow due to water uptake plant by roots are also introduced. This chapter is divided into two main parts. The first part describes the derivation of the moisture flow equation from referential element of soil from conservation of mass. A relationship between flows and the appropriate driving force or potential for moisture flow was established through Darcy's Law and incorporating root water-uptake extraction function, the sink term. The second part describes the derivation and theoretical formulation of stress-deformation development considering unsaturated soil mechanics concept in ground water field concept. The stress-deformation is partial coupled to 2-*D* axi-symmetric root water-uptake for unsaturated soil through the stress state variables and effective stress concept. The elastic moduli and constitutive relationships are required are also described.

Chapter 4 presents an approximate numerical solution of the theoretical model framework presented in Chapter 3. The problem addressed is one in which both spatial and time variations of the unknown variable, capillary potential in this case, are required. A numerical solution is then described to achieve discretisation of a two-dimensional axi-symmetric space domain and the time domain. An assessment of the theoretical formulation in the context of stress-deformation analysis was carried out to assess the robustness of the stress-deformation formulation. This chapter considers stress-deformation model by carrying verification exercise. The aim is to provide confidence in the implementation of the new stress-deformation formulation. The performance of the model is checked against independent results for a range of test problems.

Chapter 5 then moves on to explore the numerical simulation of patterns in the vicinity of mature trees and the accompanying ground displacement using the developed stress-deformation formulation. In particular the axi-symmetric form and stress-deformation model presented in Chapter 3 and 4 is explored here. The model is applied to simulate site measurements recorded by others for a mature Lime tree located on a Boulder Clay sub-soil. Non-linear hydraulic properties are obtained from independent published data. This first application of the full model aims to simulate only a spring/summer drying period and does not include a full seasonal wetting/drying cycle for Leyland Cypress tree. This second application of the full model aims to simulate only a spring/summer drying period UK case study and does not include a full seasonal wetting/drying cycle for Lime tree but, in more details than the first simulation. The third simulation presented covers a full annual cycle starting from field capacity in winter, extending through a full spring/summer drying period and including the subsequent autumn recharge for also a Lime tree. The simulation attempts to include time dependent variations in boundary conditions based on daily rainfall patterns.

Chapter 6 develops the work presented in Chapter 5 with the aim of exploring the sensitivity and parametric analysis of some of the variables involved in the simulation. Sensitivity and parametric analysis was carried to check the effect of elapse time on matric suctions and ground displacements, effect elapse time on capillary potential and effect elapse time on volumetric moisture content. Initial time step size of six hours initial time step size, twelve hours initial time step size and twenty four hours initial time step size are also investigated. Effect of actual transpiration rates, unit weights of the soils, soil initial void ratios and soil re-compression indexes are simulated and evaluated.

Chapter 7 considers how the stress-deformation formulation may be employed to provide an assessment of the significance suction changes on the stability of unsaturated soil slopes and subsequent slope settlement due vegetative ground water-uptake. Typical slope geometry and a range of initial conditions and tree locations are considered. The corresponding variation of slope settlement as the location of the tree is changed is simulated.

Overall conclusions and recommendations for further research are presented in Chapter 8.

REFERENCES

Abbaspour, K.C. (2004). Modelling soil processes for modelling flow and transport, EAWAG, pp. 15.

Aitchison, G. D. (1965). Soil properties, shear strength, and consolidation. *Proc., 6th Int. Conf. Soil Mech. Foud. Eng.*, Montreal, Canada, 3, pp. 318-321.

Aitchison, G. D. (1965) *Moisture equilibria and moisture changes in soil beneath covered areas*. A symp. In print, Aitchison, G. D. Eds. Australia: Butterworths, pp. 278.

Ali, N. (2007). *The influence of vegetation induced moisture transfer on unsaturated soils.* Doctor Philosophy, University of Wales, Cardiff.

Almeida, M.S.S., Britto, A.M. and Perry, R.H.G. (1986). Numerical modeling of a centrifuged embankment on soft clay. Can. Geotech. J., 23(20), pp. 103-114.

Angali, S. V. and Entz, M. H. (2002). Root system and water use patterns of different height sunflower cultivars. Adv. Agron. J., 94, pp. 136-145.

Alonso, E. E., Gens, A. and Josa, A. (1990). A constitutive model for partially saturated soils. Geotechnique, 40, pp. 405-430.

Alonso, E. E., Batlle F., Gens, A. and Loret, A. (1988). Consolidation analysis of partially saturated soils. *Proceedings of the 6th International Conference on Numerical Methods in Geomechanics*, Vol. 2. Innsbruck, pp. 1303-1308.

Alonso, E. E., Gens, A. and Hight, D. W. (1987). Special problem soils. *Ninth Europ. Conf. on Soil Mechanics and Foundation Engineering*, pp. 1087-1146.

Bear, J. (1979). *Hydraulics of Groundwater*. London: McGraw-Hill.

Bell, J. P. (1976). *Neutron Probe Practice*. Institute of Hydrology, Wallingford.

Biddle, P. G. (2001). Tree root damage to buildings. ASCE Geotech. Special Publication. 115, pp. 1-23.

Biddle, P. G. (1998). *Tree Root Damage to Buildings*. Willowmead Publishing Ltd, Wantage.

Biddle, P. G. (1983). Patterns of soil drying and moisture deficit in the vicinity of trees on clay soils. Geotechnique, 33(2), pp. 107-126.

Biot, M. A. (1941). General theory of three-dimensional consolidation. J. Appl. Phys., 12, pp. 155-164.

Bishop, A. W. (1959). The principle of effective stress. Tecknish Ukebland; 106(39), pp. 859-863.

Bishop, A. W. and Blight, G. E. (1963). Some aspects of effective stress in saturated and unsaturated soils. Geotechnique, 13, pp. 177-197.

Bishop, A. W. and Henkel, D. J. (1962). *The Measurement of Soil Properties in the Triaxial Test.* (2nd edn). Edward Arnold: England, London, pp. 227.

Blight, G. E. (2005). Dessication of clay by grasses, bushes and trees. Geotechnical and Geological Engineering 23, pp. 679-720.

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

Bolzon, G., Schrefler, B. A. and Zienkiewicz, O. C. (1996). Elastoplastic soil constitutive laws generalised to partially saturated states. Geotechnique 46, pp. 279-289.

Bouma, J., Jongmans, A. G., Stein, A. and Peek, G. (1989). Characterising Spatially Variable Hydraulic Properties of a Boulder Clay Deposit in the Netherlands. Geoderma, 45, pp. 19-29.

Bozozuk, M. (1962). Soil shrinking damages shallow foundations at Ottawa, Canada. Res. Paper 163, Div.Building Research, Canada NRCC.

Bozozuk, M. and Burn, K. N. (1960). Vertical ground movement near Elm trees. Geotechnique, 10, pp. 19-32.

Brackley, I. J. A. (1971). Partial collapse in unsaturated expansive clay. *Proc., 5th Regional Conf. SMFE*, South Africa, pp. 23-30.

Broadbridge, P. and White, I. (1988). Constant rate rainfall infiltration: A versatile nonlinear model. 1. Analytical solution. Water Resources Research, 24 (1), pp. 145-154.

Brooks, R. H. and Corey, A. T. (1964). Hydraulic properties of porous media. Colorado State University Hydrology Paper no. 3, Fort Collins, pp. 27.

Brown, R. W. (1982). *Determination of leaf osmotic potential using thermocouple psychrometers*. In: Psychrometry in water relations research (eds. Brown R. W. and Van Haveren B. P.), Utah Agric. Res.Stn. Utah State Univ.Burland JB.

Some aspects of the mechanical behaviour of partly saturated soils. In: *Proceedings of the Conference on Moisture Equilibria and Moisture Changes in Soil Beneath Covered Areas*, Aitchison GD (ed.). London: Butterworths, 1965; pp. 270-278.

Buckler, L., Lafolie, F., Doussan, C. and Bussieres, F. (2004). Modelling soil-root water transport with non-uniform water supply and heterogeneous root distribution. Plant Soil, 260(1-2), pp. 205-224.

Buckingham, E. (1907). Studies on the Movement of Soil Moisture. US Department of Agriculture Bureau Soils, 38, Washington DC, pp. 61.

Buckingham, E. (1904). Contributions to our knowledge of the aeration of soils. Bull. 25, United States. Department of Agriculture. Washington, DC, pp. 50.

Building Research Establishment (2004). *Controlling Water Use of Trees to Alleviate Subsidence Risk.* Horticulture LINK project 212, University of Cambridge.

Building Research Establishment (1999). *Low-rise building foundations: the influence of trees in clay soils*. A Building Research Establishment Publication.

Buresh, R. J. and Tian, G. (1998). Soil improvement by trees in sub-Saharan Africa. Agroforestry Systems, 38, pp. 51-76.

Burdine, N. T. (1953). Relative permeability calculation from pore size distribution data. AIMME Petroleum Transactions, 198, pp. 71-77.

Burland, J. B. (1965). *Some aspects of the mechanical behaviour of partly saturated soils. Moisture Equilibria and Moisture Changes in the Soils Beneath Covered Areas,* G. D. Aitchison, ed., Butterworth, Sydney, Australia, pp. 270-278.

Cameron, D. A. (2001). The extent of soil desiccation near trees in a semi-arid environment. Geotechnical and Geological Engineering 19, pp. 357-370.

Cameron, D. A. and Walsh, P. F. (1984). *Damage to buildings on clay soils*. National Trust of Australia (Victoria), Technical Bulletin 5.1.

Cameron, D. A. and Earl, I. (1982). *Trees and Houses*: a Question of Function. Cement and Concrete Association of Australia, pp. 20.

Carslaw, H. S. and Jaeger, J. C. (1959). *Conduction of Heat in Solids*. 2nd Edition. Oxford: Oxford University Press, pp. 510.

Celia, M. A., Bouloutas, E. T. and Zarba, R. L. (1990). A general mass conservative numerical solution of the unsaturated flow equation. Water Resources Research, 26, pp. 1483-1496.

Chang, Y. Y. and Corapcioglu, M. Y. (1997). Effect of roots on water flow in unsaturated soils. Journal of Irrigation and Drainage Engineering, pp. 202-209.

Chahine, M. T. (1992). The hydrological cycle and its influence on climate. Nature 359, pp. 373-380.

Chen, F. (1988). Foundation on Expansive Soils. 1st Edtn. NY: Elsevier, pp. 280.

Childs, E. C. and Collis, G. N. (1950). The Permeability of porous Materials. *Proc. Roy. Soc., London*, 201, pp. 392-405.

Chun-Ta, L. and Gabriel, K. (2000). The dynamic role of root-water uptake in coupling potential to actual transpiration. Adv. in Water Res. 23, pp. 427-439.

Claude, D., Lois P. and Gilles, V. (1998). Modelling of the Hydraulic Architecture of Root Systems: An Integrated Approach to Water Absorption Model Description, Annals of Botany 81, pp. 213-223.

Clausnitzer, V. and Hopmans, J. V. (1994). Simultaneous modelling of transient three-dimensional root growth and soil water flow. Plant soil 164, pp. 299-314.

Clemson University (2007). *Home & Garden Information Center* - Leyland Cypress, http://hgic.clemson.edu/factsheets/hgic1013.htm. Clemson University cooperating with U.S. Department of Agriculture, South Carolina.

Clough, R. W. (1960). The finite element method in plane stress analysis. Paper presented at *The 2nd Conference on Electronic Computation, American Society of Civil Engineering*, New York.

Coppin, N. J. and Richards I. J. (1990). Use of Vegetation in Civil Engineering. London: Butterworths.

Coussy, O. (1995). *Mechanics of porous continua*. New York: JohnWiley.

Cowen, I. R. (1965). Transport of water in the soil-plant atmosphere system. Journal of Applied Ecology. 2, pp. 221-239.

Croney, D. (1977). *The design and performance of road pavements*. London: HMSO Publication, pp. 647.

Cutler, D.F., Gasson, P.E. and Farmer, M. C. (1990). The wind blown tree survey: Analysis of results. Arboricultural Journal, 14, pp. 265-286.

Cutler, D. F. and Richardson, I. B. K. (1989). *Tree roots and buildings.* Singapore: Longman Scientific and Technical.

Cutler, D. F. and Richardson, I. B. K. (1981). *Trees and Buildings*. London: Construction Press.

Dawson, L. A., Duff, E. I., Campbell, C. D. and Hirst, D. J. (2001). Depth distribution of cherry (Prunus avium L.) tree roots as influenced by grass root competition. Plant and Soil, 231, pp. 11-19.

de Boer, R. and Ehlers, W. (1990). The development of the concept of effective stresses. Acta Mech*.,* 83, pp. 77-92.

Debnath, K. and Chaudhuri, S. (2010). Laboratory experiments on local scour around cylinder for clay and clay–sand mixed beds, Engineering Geology, Vol. 111, issue 1-4. Pp. 51-61.

Dekker, S. C., Bouten, W. and Verstraten, J. M. (2000). Modelling forest transpiration from different perspectives. Hydro. Proc. 14, pp. 251-260.

Derbaum. (2005). *Lime*. http://www.flickr.comphotos/derbaum/15318101. Flickr Blog.

Dobson, M. C. (1995). *Tree root systems*. Arboriculture Research and Information Note. Arboricultural Advisory and Information Service, Farnham.

Dobson, M. C. and Moffat, A .J. (1993). The potential for woodland establishment on landfill sites. Department of the Environment. London: HMSO Publication.

Doussan, C., Gilles, V. and Lois, P. (2008). Modelling of the Hydraulic Architecture of Root Systems: An Integrated Approach to Water Absorption-Distribution of Axial and Radial Conductances in Maize, Annals of Botany 81, pp. 225-232.

Driscoll, R. (1983). The influence of vegetation on the swelling and shrinkage of clays in Britain, Geotechnique, 33 (2), pp. 93-105.

Dunin, F. X., Mcilory, I. C. and Oloughlin, E. M. (1985). *A lysimeter characterization of evaporation by eucalypt forest and its representativeness for the local environment.* Forest-Atmosphere Interaction. Dordrecht: D.Reidal Publishing Company, pp. 271-291.

Erkki, A. (1996). Modelling non-uniform soil water uptake by a single plant root Plant and Soil 186. pp. 237-243.

Fan, C. H. and Su, C. F. (2008). Role of roots in the shear strength of root-reinforced soils with high moisture content. Ecol. Eng. 33, pp. 157-166.

Fasong, Y. and Zhiming, L. (2005). Analytical solutions for vertical flow in unsaturated rooted soils with variable surface fluxes. Vadose Zone J. 4, pp. 1210-1218.

Fatahi, B., Khabbaz, H. and Indraratna, B. (2010). Bioengineering ground improvement considering root water uptake model. Ecological Engineering 36, pp. 222-229.

Fatahi, B., Khabbaz, H. and Indraratna, B. (2009). Parametric studies on bioengineering effects of tree root-based suction on ground behavior. Ecological Engineering 35, pp. 1415-1426.

Feddes, R. A., Hoff, H., Bruen, M., Dawson, T., Rosnay, P., Jackson, R. B., Kabat, P., Lilly, A. and Pitmank, A. J. (2001). Modelling root water uptake in hydrological and climate models. American Metrological Society 82(12), pp. 2797-2809.

Feddes, R. A., Kowalik, P. J. and Zaradny, H. (1978). *Simulation of field water use and crop yield.* Wageningen Center for Agriculture and Documentation, Wageningen, pp. 189.

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

Feddes, R. A., Bresler, E. and Neuman, S. P. (1974). Field test of a modified numerical model for water uptake by root systems. Water Resources Research, 10(6), pp. 1199-1206.

Francis, P. E. and Pidgeon, J. D. (1982). A model for estimating soil moisture deficits under cereal crop in British I: Development. J. Agric. Sci. 98, pp. 651-661.

Fredlund, D. G. and Hung, V. Q. (2001). Predictive of volume change in an expensive soil as a result of vegetation and environmental changes. *Pro. Of ASCE Conf. on expansive clay soils and vegetative influence on shallow foundations, Geotechnical Special Publication*. Houston, Texas, Reston, Vol. 115, pp. 24-43.

Fredlund, D. G. and Rihardjo, H. (1993). *Soil Mechanics for Unsaturated Soil*. New York: John Wiley and Sons, pp. 346-373.

Fredlund, D. G. (1979). Appropriate concepts and technology for unaturated soils. Can. Geotech. J., 16, pp. 121-139.

Fredlund, D. G., Morgenstern, N. R. and Widger, R. A. (1978). The shear strength of unsaturated soil. Can. Geotech. J., 15, pp. 313-321.

Fredlund, D. G. and Morgenstern, N. R. (1977). Stress state variable for unsaturated soils, ASCE Journal of Geotechnical Engineering, 103, pp. 447-466.

Fredlund, D. G. and Morgenstern, N. R. (1976). Constitutive relation for volume change in unsaturated soils. Can. Geotech. J., Vol. 13, No. 3, pp. 261-276.

Freeze, R. A. and Witherspoon P. A. (1966). Theoretical analysis of regional ground water flow 1. Analytical and numerical solutions to the mathematical model. Water Resources Research, 2 (4), pp. 64-656.

Gardner, W. H. (1988). A Historical Perspective on Measurement of Soil and Plant Water Status. Irrig. Sci. 9, pp. 255-264.

Gardner, W. R. (1974). The Permeability Problem. Soil Sci. J., 117(5), pp. 243-249.

Gardner, W. R. (1964). Relation of root distribution to water uptake and availability. Agronomy Journal, 56, pp.4-45.

Gardner, W. R. (1960). Dynamic aspects of water availability to plants. Soil Science, 89 (2), pp. 263-273.

Gardner, W. R. (1957). Some steady-state solutions of the unsaturated moisture flow equation with application to evaporation from a water-table, Soil Science, 85 (4), pp. 228-232.

Gardner, W. R. and D. Kirkham, D. (1952). Determination of soil moisture by neutron Scattering. Soil Science, 73, pp. 391-401.

Gardner, W., Israelsen, O. W., Edlefsen, N. E. and Clyde, D. (1922). The capillary potential function and its relation to irrigation practice. Physics Review, 20, pp. 196, Abstract.

Gowda, P., Chavez Eguez, J.L., Colaizzi, P.D., Evett, S.R., Howell, T.A., Tolk, J.A. (2008). ET mapping for agricultural water management: Present status and challenges. Irrigation Science. 26, pp. 223-237.

Gens, A. (1995). Constitutive modelling: application to compacted soils. In: Alonso E. E., Delage P (eds). *Proceedings of 1st International Conference on Unsaturated Soil,* vol. 3. Balkema: Rotterdam, pp. 1179-1200.

Gens, A. and Alonso, E. E. (1992). A framework for the behavior of unsaturated expansive soil. Can. Geotech. J. 29, pp. 1013-1032.

Genuchten, M. T. V. and Nielsen, D. R. (1985). On describing and predicting the hydraulic properties of unsaturated soils. A. Geophysicae, 3 (5), pp. 615-628.

Genuchten, M. T. V. (1980). A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J. 44, pp. 892-898.

Goldman, L. J., Greenfield, L. I., Damle, A. S., Kingsbury, G. L., Northeim, C. M. and Truesdale, R. S. (1988). Design, Construction, and Evaluation of Clay Liners for Waste Management Facilities, EPA/530/SW-86/007F, U.S. Environmental Protection Agency, Cincinnati, OH, Chapter 6.

Gong, D., Kang, S., Zhang, L., Du, T. and Yao, L. (2006). A two-dimensional model of root water uptake for single apple trees and its verification with sap flow and soil water content measurements. Agricultural Water Management, 83, pp. 119-129.

Green, S. R., Vogeler I., Clothier, B. E., Mills, T. M. and Dijssel, C. (2003). Modeling water uptake by a mature apple tree. Aust. J. Soil Res. 41 (3), pp. 365-380.

Green, R. E. and Corey, J. C. (1971). Calculation of Hydraulic Conductivity: A further Evaluation of Some Predictive Methods. Soil Sci. Soc. Am. J., 35, pp. 3-8.

Gui-Rui Y., Zhuang J., Nakayama K. and Jin Y. (2007). Root water uptake and profile soil water as affected by vertical root distribution. Plant Ecol., 189, pp. 15-30.

Hao, X., Zhang, R. and Kravchenko, A. (2005). Effects of root density distribution models on root water-uptake and water flow under irrigation. Soil Sci., 170(3), pp. 167-174.

Hills, R. G., Porro, I., Hudson, D. B. and Wierenga, P. J. (1989). Modeling one dimensional infiltration into very dry soils: 1. Model development and evaluation. Water Resources Research, 25 (6), pp.1259-1269.

Hillel, D., Beek, V. and Talpaz H. (1975). A microscopic-scale model of soil water uptake and salt movement to plant roots. Soil Science 120(5), pp. 385-398.

Hinton, E. and Owen, D. R. J. (1989). *Finite Element Programming*. London: Academic Press.

Holland, J. E. (1979). Trees - how they can affect footings. POAV J., pp. 11-14.

Homaee, M., Dirksen, C. and Feddes, R. A. (2002a). Simulation of root water uptake I. Non-uniform transient salinity using different macroscopic reduction functions. Agric. Water Management 57, pp. 89-109.

Homaee, M., Dirksen, C. and Feddes, R. A. (2002b). Simulation of root water uptake II. Non-uniform transient water stress using different macroscopic reduction functions. Agric. Water Management 57, pp. 111-126.

Homaee M., Dirksen C. and Feddes R. A. (2002c). Simulation of root water uptake III. Non-uniform transient combined salinity and water stress using different macroscopic reduction functions. Agric. Water Managt. 57, pp. 127-144.

Hopkins, W. G. (1999). *Introduction to Plant Physiology*. USA: John Wiley and Sons Inc.

Hung, V. Q. and Fredlund, D. G. (2000). Volume change prediction in expansive soils using a two dimensional finite element method. *Proceeding of Asian Conference on unsaturated soils* in Singapore, pp. 231-236.

Hung, V. Q. and Fredlund, D. G. (2006). Challenges to modeling of heave in expansive soil, Can. Geotech.l J., 43, pp. 1249-1272.

Indraratna, B. and Khabbaz, H. (2008). Conceptual Development and Numerical Modelling of Vegetation Induced Suction and implications on Rail Track Stabilisation. *The 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG)* 1-6 October, Goa, India, pp. 4335-4344.

Indraratna, B., Fatahi, B. and Khabbaz, H. (2007). *Finite element modeling of soil-vegetative interaction*. In: Schanz (eds) Theoretical and numerical unsaturated soil mechanics. Springer Proc. in Physics 113, pp. 211-223.

Indraratna, B., Fatahi, B. and Khabbaz, H. (2006). Numerical analysis of matric suction effects of the roots. Geotechnical Engineering 159, pp. 77-90.

Jackson, R. B., Sperry, J. S. and Dawson, T. E. (2000). Root water uptake and transport: using physiological process in global predictions. Trends Plant Sci. 5, pp. 482-488.

Jackson, P. C., Cavelier, J., Goldstein, G., Meinzer, F. C. and Holbrook, N. M. (1995). Partitioning of water resources among plants of a lowland tropical forest. Oecologia 101, pp. 197-203.

Jackson, D. and Rushton, K. R. (1987). Assessment of Recharge Components for a chalk aquifer unit. Journal of Hydrology, 92, pp. 1-15.

Jaksa, M. B., Kaggwa, W. S., Woodburn, J. A. and Sinclair, R. (2002). Influence of large gums trees on the soil suction profile in expansive clays. Aust. Geomechanics, Vol. 71, No. 1, pp. 23-33.

Javandel, I. and Witherspooon, P. A. (1968). Application of the finite-element method to transient flow in porous media. Society of Petroleum Engineers Journal, 8, pp. 241-252.

Jennings, J. E. B. and Burland, J. B. (1962). Limitations to the use of effective stresses in unsaturated soils. *Geotechnique,* 12, pp. 125-144.

Jones and Jones (1987). *Treating Expansive Soils*. Civil Engineering Magazine, ASCE, Vol. 57, No. 8.

Jones, D. E. and Holtz, R. D. (1973). Expansive Soil- The Hidden Disaster. Civil Engineering, ASCE, Vol. 43, No. 8, pp. 49-51.

Justo, J. L. and Saertersdal R. (1979). Design parameters for special soil conditions. General Report, *Proc. 7th Eur. Conf. SMFE* 4, pp. 181-208.

Karen, J. E. and Philip, W. R. (1999). Comparative patterns of phenology and growth form diversity in two winter rainfall deserts: the Succulent Karoo and Mojave Desert ecosystems. Plant Ecology, 142, pp. 97-104.

Kayadelen, C. (2008). Estimation of effective stress parameter of unsaturated soils by using artificial neural networks, Int. J. Num. Anal. Meth. Geomech. 32(9) pp. 1087-1106.

Khalili N., Habte, M. A. and Zargarbashi, S. (2008). A full coupled flow deformation model for cyclic analysis of unsaturated soils including hydraulic and mechanical hysteresis, Computers and Geotechnics 35, pp. 872-889.

Khalili, N., Geiser, F. and Blight, G. E. (2004). Effective stress in unsaturated soils: review with new evidence. International Journal of Geomechanics (ASCE), 4(2), pp. 115-126.

Khalili, N. and Loret, B. (2001). An elasto-plastic model for nonisothermal analysis of flow and deformation in unsaturated soils: Formulation. Int. J. Solids Struct., 38, pp. 8305-8330.

Khalili, N. (2000). *Application of the effective stress principle to volume change in unsaturated soils*. In: Rahardjo H, *et al*., (eds). Unsaturated Soils for Asia, Balkema: Rotterdam, pp. 119-124.

Kirkham, D. and Powers, W. L. (1972). *Advanced Soil Physics*. New York: Wiley Inter-science.

Klute, A. (1972). The determination of the hydraulic conductivity and diffusivity of unsaturated soils. Soil Sci. J. 113 (4), 264-276.

Klute, A. (1952). A numerical method for solving the flow equation for water in unsaturated soil. Soil Sci. 20, pp. 317-320.

Knox, B., Ladiges, P. and Evans, B. (1995). *Biology.* Australia: McGraw-Hill.

Knoch, B. C., Slack, D. C. and Larson C. L. (1984). Predicting direct recharge of surficial aquifers. Transactions of the ASAE, pp. 1739-1744.

Kohgo, Y., Nakano, M. and Miyazaki, T. (1993). Theoretical aspects of constitutive modelling for unsaturated soils. Soils and Foundations, 33, pp. 49-63.

Kozlowski, T. T. (1982). Water supply and tree growth. Forestry Abstracts, 43, 2, pp. 57-95.

Krahn, P. J. and Fredlund, D. G. (1972). On total, matric and osmotic suction, Soil Science 114, pp.339-348.

Ladd, C. C. R. and Foott, R. (1974). New design procedure for stability of soft clays. ASCE, J. Geotech. Eng. 100 (GT7), pp. 763-786.

Lai, C. T. and G. Katul (2000). The dynamic role of root-water uptake in coupling potential to actual transpiration. Advances in Water Resources 23, pp. 427-439.

Lambe, T. W. and Whitman, R. V. (1969). *Soil Mechanics*. New York: John Wiley and Sons Inc., pp. 363-365.

Li, K. Y., Jong, R. D., Coe, M. T. and Ramankutty, N. (2006). Root-Water-Uptake Based upon a New Water Stress Reduction and an Asymptotic Root Distribution Function. Earth Interactions, 10(14), pp. 1-22.

Li, K.Y., Jong, R.D. and boisvert, J.B. (2001). An exponential root water-uptake model with water stress compensation J. of Hydrology 252, pp. 189-204.

Li K. Y., Jong R. D. and boisvert J. B. (1999). An exponential root water-uptake model, Can. J. of Soil Science 79, pp. 333-343.

Li J, and Cameron, D. A. (1995). Finite element analysis of deep beams in expansive clays. In: Alonso E. E. and Delage P. (eds). *Proceedings of the 1st International Conference on Unsaturated Soils,* Vol. 2. Balkema: Rotterdam, pp. 1109-1115.

Loret, B. and Khalili, N. (2000). A three phase model for unsaturated soils. Int. J. Numer. Analyt. Meth. Geomech., 24, pp. 893-927.

Loss Prevention Council (1995). Report LPR4. *Subsidence and Domestic Housing Survey: Analysis of Results*. London: Loss Prevention Council.

Low, P. F. and Margheim, J. F. (1979). The swelling of clay I: Basic concepts and empirical equations. Soil Sci. Society of America Journal 43, pp. 473-481.

Lu, N. and William, J. L. (2006). Suction Stress Characteristic Curve for Unsaturated Soil. *ASCE, Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 132, No. 2, pp. 133-135.

Luis, G. (2003). Determination of relative moisture content. Handbook of plant ecophysiology Techniques.

Lytton, R. L. (1994). *Prediction of movement in expansive clay*. In Vertical and Horizontal Deformations of Foundations and Embankments: *Proceedings of Settlement '94*, College Station, Texas, 16-18 June 1994. Edited by A. T. Yeung and G. Y. Feaalio. American Society of Civil Engineers, Geotechnical Special Publication 40, pp. 1827-1845.

Lytton, R. L. (1977). *Foundation on expansive soils*. In Numerical methods in geotechnical engineering. Edited by C. S. Desai and J. T. Christian. New York: McGraw-Hill, pp. 427-457.

MacNeil, D. J., Steele, D. P., McMahoii, W. and Carder, D. R. (2001). Vegetation for slope stability. Prepared for Quality Services, Civil Engineering, Highways Agency, pp.48.

Mathieu, J., Tom, S., Jan V. and Harry, V. (2008). Use of a three-dimensional detailed modeling approached for predicting root water-uptake, Vadoze Zone Journal, 7 (3), pp. 1079-1088.

Mathur, S. and Rao S. (1999). Modeling water uptake by plant roots. Journal of Irrigation and Drainage Engineering, 125(3), pp. 159-165.

Mathur, S. (1999). Settlement of soil due to water uptake by plant roots. Int. J. Numerical Anal. Mech. Geomech., 23 pp. 1349-1357.

Matyas, E. L. and Radhakrishna, H. S. (1968). Volume change characteristics of partially saturated soils. *Geotechnique,* 18, pp. 432-448.

McGinnity, B. T., Fitch T. and Rankin, W. J. (1998). A systematic and cost-effective approach to inspecting, prioritizing and upgrading London Underground Earth Structures. *ICE Proceedings of Seminar, Value of Geotechnics in Construction.* pp. 309-332.

McInnes, D .B. (1986). Drying effect of different verge planted tree species on urban roads. *Proc. 13 ARRB, 5th REAAA Comb Conf.*, Vol.13, Partt 4, pp 54-66.

McKeen, R. G. (1992). A model for predicting expansive soil behaviour. *Proc., 7th Int. Conference on Expansive Soils*, Dallas, Vol 1, pp. 1-6.

Meteorological Rainfall Data (1979-1980), (2006). Meteorological Office. United Kingdom: Exeter.

Millington, R. J. and Quirk, J. P. (1961). Permeability of Porous Solids. Trans. Faraday Soc., 57, pp. 1200-1207.

Miranda, A.N. (1988). *Behaviour of small earth dams during initial filling*. Doctor Philosophy, Colorado State University, Fort Collins, Colorado.

Mohammed, Q. S. S. (2008). Finite element analysis of consolidation problem in several types of cohesive soils using the bounding surface model, ARPN journal of engineering and applied sciences, Vol. 3, no. 6, pp. 234.

Modaressi, A. and Abou-Bekr. N. (1994). A unified approach to model the behaviour of saturated and unsaturated soils. *Proceedings of the 8th International Conference on Computer Methods and Advances in Geomechanics*. Balkema: Rotterdam, pp. 1507-1513.

Molz, F. J. (1981). Models of water transport in the soil-root system. Water Resources Research, 17, pp. 1245-1260.

Molz, F. J. (1976). Water transport in the soil-root system. Water Resources Research, 12(4), pp. 805-808.

Molz, F. J. and Remson, I. (1970). Extraction term models of soil moisture use by transpiring plants. Water Resources Research, 6, pp. 1346-1356.

Moreno, G., Obrador, J. J., Cubera, E. and Dupraz, C. (2005). Fine root distribution in Dehesas of Central-Western Spain. Plant and Soil, 277, pp. 153-162.

Moroke, T. S., Schwartz, R. C., Brown, K. W. and Juo, A. S. R. (2005). Soil water depletion and root distribution of three dryland crops. Soil Sci. Soc. Am. J. 69, pp. 197-205.

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

Mualem, Y. (1976). A new model for predicting the hydraulic conductivity of unsaturated porous media, Water Resour. Res. 12, pp. 513-522.

Naiser, D. D., JR. (1997). *Procedures to predict vertical differential soil movement for expansive soils*. Masters Thesis. Texas A and M Univ., College Station, Texas.

Narasimhan, T. N. (1998a). Hydraulic characterization of aquifers, reservoir rocks, and soils: A history of ideas. Water Resources Research, 34 (1), pp. 33-46.

Narasimhan, T. N. (1998b). Something to think about... Darcy-Buckingham's law. Ground Water, 36 (2), pp. 194-195.

Navarro, V., Candel, M., Yustres, A., Sanchez, J. and Alonso, J. (2009) Trees, soil movement and foundation, Computers and Geotechnics 36, pp. 810-818.

Neumann S. P., Feddes R. A. and Bresler E. (1975). Finite element analysis of two-dimensional flow in soil considering water uptake by roots: I Theory, Soil Sci. Soc. Am. J. 35, pp. 224-230.

Neuman, S. P. (1973). Saturated-unsaturated seepage by finite elements. ASCE Journal of the Hydraulics Division, 99, pp. 2233-2250.

Ng, C. W. W. (1998). Observed performance of multi-propped excavation in stiff clay, J. Geoenv. 124(9), pp. 889-906.

Nielsen, D. R., vanGenuchten, M. Th. and Biggar, J. W. (1986).Water flow and solute transport processes in the unsaturated zone. Water Resour. Res., 22(9), pp. 89-108.

Nisbet, T. R. (2005). *Water Use by Trees*. Forestry Commission, Edinburgh, pp. 1-8,

Nimah, M. N. and Hanks, R. J. (1973). Model for estimating soil water, plant and atmospheric interrelations. I: Description and sensitivity. *Proc. Soil Sci. Soc. Am*. 37, pp. 522–527.

Nyambayo, V.P. and Potts, D.M. (2010). Numerical simulation of evapotranspiration using a root water uptake model, Computers and Geotechnics 37, pp.175-186.

Ojha, C. S. P. and Rai, A.K. (1996). Nonlinear root-water uptake model. Journal of Irrigation and Drainage Engineering, 122(4), pp. 198-202.

O'Malley, A. P. K. and Cameron D. A. (2002). The influence of trees on soil moisture, dwellings and pavements in an urban environment. University of South Australia, School of Geoscience, Minerals and Civil Engineering Mawson Lakes Campus, Local Goverment Report, pp. 7-8.

O'Malley, A. P. K. (2001). *Water relations of four urban street tree species using a Wescor in-situ hygrometer in the City of Salisbury, South Australia*. Honours Thesis, University of South Australia, p. 123.

Parker, J. C., Amos, D. F. and Zelazny, L. W. (1982). Water adsorption and swelling of clay minerals in soil systems. Soil Science Society of America Journal 46, pp. 450-456.

Pereira, J. H. F. and Fredlund, D. G. (2000). Volume change behaviour of a residual soil of gneiss compacted at metastable-structured conditions. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 126, pp. 907-916.

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

Philip, J. R. (1957). The theory of infiltration 1: The infiltration equation and its solution. Soil Sci., 83, pp. 345-357.

Philip, J. R. (1955). Numerical solution of equation of the diffusion type with diffusivity concentration dependent, Transactions of Faraday Society 51, pp. 885-892.

Pile, K. C. (1984). The deformation of structures on reactive clay soils. *Proc., 5th Int. Conference on Expansive Soils*, Adelaide, pp. 292-299.

Polley, H. W., Hyrum B. J. and Charles R. T. (2002). Woody invasion of grasslands: evidence that CO_2 enrichment indirectly promotes establishment of Prosopis glandulosa. Plant Ecology, 164, pp. 85-94.

Potter, W. (2006). *The feasibility of improving rail infrastructure by using native vegetation on clay soils*. Master of Engineering by Research Thesis. University of South Australia, Australia.

Powrie, W., Davies, J. N. and Britto, A. M. (1992). A cantiliver retaining wall supported by a berm during the temporary work activities, *ICE conference on retaining structures*, Robinson College, Cambridge, pp. 418-428.

Prasad, R. (1988). A linear root water uptake model. J. Hydrology, 99, pp. 297-306.

Raats, P. A. C. (1974). Steady flow of water and salt in uniform soil profiles with plant roots. Soil Sci. Am. Proc. 38, pp. 717-722.

Raats, P. A. C. and Klute, A. (1969). One-dimensional simulation motion of the aqueous phase and the solid phase of unsaturated and partially saturated porous media, Soil Sci. 107, pp. 329-333.

Rees, S. W. and Ali, N. (2006). Seasonal water uptake near trees: A numerical and experimental study. Geomech. Geoeng.Vol. 1, No. 2, pp. 129-138.

Rees, S. W. (1990). *Seasonal Ground Movement Effects on Buried Services,* Doctor Philosophy, University of Wales, Cardiff.

Remson, I., Appel, C. A. and Webster, R. A. (1965). Ground-water models solved by digital computer, Journal of Hydraulics Division, American Society of Civil Engineers, 91(HY3), pp. 243-274.

Rice, J. R. and Cleary, M. P. (1976). Some basic stress diffusion solutions of fluid saturated elastic porous media with compressible constituents. Rev. Geophys. Space Phys., 14, pp. 227-291.

Richards, B. G. (1992). Modelling interactive load-deformation and flow processes in soils, including unsaturated and swelling soils. John Jaeger Memorial

Lecture, *Proceedings of the 6th Asut-NZ Conference on Geomechanics*, Christchurch, New Zealand, pp. 18-37.

Richards, B. G., Peter, P. and Emerson, W. W. (1983). The effects of vegetation on the swelling and shrinking of soils in Australia. Geotechnique, 33(2), pp. 127-139.

Richards, B .G. and Chan, C. Y. (1971). Theoretical analyses of subgrade moisture under environmental conditions and their practical implications. Aust. Road Research, 4, 6, pp. 32-49.

Richards, L. A., Gardner, W. R. and Ogata, G. (1956). Physical processes determining water loss from soil. *Soil Science Society of America Proceedings*, 20, pp. 310-314.

Richards, L.A. (1931). Capillary conductance of liquids through porous mediums, Physics 1, pp. 318-333.

Richards, L. A. (1928). The usefulness of capillary potential to soil-moisture and plant investigators. Journal of Agricultural Research, 37, pp. 719.

Ridley, A., Ginnity, M. and Vaughan, P. (2004). Role of pore water pressures in embankment stability. Geotechnical Engineering, 157, pp.193-198.

Rockey, K. C., Evans, H. R., Griffiths, D. W. and Nethercot, D. A. (1983). *TheFinite Element Method.* London: Collins.

Ross, P. J. (1990). Efficient numerical methods for infiltration using Richards's equation. Water Resources Research, 26 (2), pp. 279-290.

Rowse, H. R. Stone, D. A. Gerwitz, A. (1978). Simulation of the water distribution in soil II: The model cropped soil and its comparison with experiment. Plant Soil 49, pp. 533-550.

Russell, D., Ellis E. O'Brien A. S. and McGinnity B. (2000). Role of vegetation on the stability and serviceability of railways embankments. *1st Int. Conf. on Railway Engineering*, United Kingdom: London.

Russell, A. R., and Khalili, N. (2006). A unified bounding surface plasticity model for unsaturated soils. Int. J. Num. Anal. Meth. Geomech. 30(3) pp. 181-212.

Samuels, S. G. (1975). Some properties of the Gault Clay from Ely-Ouse Essex water tunnel. Geotechnique, 25(2), pp. 239-264.

Schreiner, H. D. (1986). *State of the art review of expansive soils for TRRL*. London: Imperial College.

Schafer, W. M. and Singer, M. J. (1976). Influence of physical and mineralogical properties on swelling of soils in Yolo County, California. Soil Science Society of America Journal 40, pp. 557-562.

Science and Plants for Schools (2007). *Common Lime*. (Tilia x europaea). Homerton College, United Kingdom: Cambridge.

Silvestri, V., Souliec, M., Lafleur, J., Sarkis, G. and Bekkouche, N. (1992). Foundation problems in Champlain clays during droughts II. Case histories. Can. Geotech. J., 29, pp. 169-187.

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

Simon, A., Curini, A., Darby, S. E. and Langendoen, E. J. (2000). Bank and near-bank processes in an incised channel. Geomorphology, 35, pp. 193-217,

Simon, A. and Darby, S. E. (1999). *The nature and significance of incised river channels.* In: Incised River Channels: Processes, Forms, Engineering and Management, John Wiley and Sons, pp. 3-18.

Simunek, J., Vogel, T. and vanGenuchten, M. Th. (1992). The SWMS 2D code for simulating water flow and solute transport in two dimensional variably saturated media, Research ReportvNo. 126, US Salinity Lab., ARS USDA Riverside.

Smiles, D. E. and Rosenthal, M. J. (1968). The movement of water in swelling materials, Aust. J. Soil Res. 6. pp. 237-248.

Sposito, G. (1987). *The "physics" of soil water physics*. In: History of Geophysics, Vol. 3, edited by E. R. Landa and S. Ince. AGU, Washington, D.C., pp. 93-98.

Srivastava, R. and Yeh, T. J. (1991). Analytical solutions for one-dimensional, transient infiltration toward the water-table in homogeneous and layered soils. Water Resources Research, 27(5), pp. 753-762.

Stallman, R. W. (1956). Use of numerical methods for analyzing data on groundwater levels. Intern. Assoc. Sci. Hydrol. Publ. 41, pp. 227-231.

Stephensen, D. B. (1995). *Vadose Zone Hydrology.* Boca Raton, Florida: CRS Press, Inc., Pp. 339.

Steudle, E. (1994). Water transport across roots. Plant Soil, 167, pp. 79-90.

Stone, W. J. (1999). *Hydrology in Practice*. New Jersey: Prentice Hall.

Sun, H. L., Li, S. C., Xiong, W. L., Yang, Z. R., Cui, B. S. and Yangc, T. (2008). Influence of slope on root system anchorage of Pinus yunnanensis. Ecol. Eng. 32, pp. 60-67.

Swatzendruber, D. (1968). The applicability of Dacy's Law. *Proc. SSSA*, 32, pp. 1-18.

Taboada, M. A. (2003). *Soil Shrinkage Characteristics in Swelling Soils,* Lecture given at the College on Soil Physics Trieste, 3-21 March 2003LNS0418038.

Taylor, C. and Hughes, T. G. (1981). *Finite Element Programming of the Navier-Stokes Equations*. Swansea: Pineridge.

Taylor, H. M. and Klepper, B. (1978). Role of rooting characteristics, Adv. Agron. 30, pp. 99-128.

Terzaghi, K. (1936). The shear resistance of unsaturated soil, *Proc., 1st Int. Conf. on Soil Mechanics and Foundation Engineering*, Harvard Printing Office, Cambridge, Mass., pp. 54-56.

Terzaghi, K. (1925). *Principles of soil mechanics*: summary of experimental results of clay and sand Eng. News Rec., 3, pp. 98.

Thomas, H. R. and He, Y. (1995). Analysis of coupled heat, moisture and air transfer in a deformable unsaturated soil. Geotechnique 45, pp. 677-689.

Thomas, H. R. and Rees, S. W. (1993). The numerical simulation of seasonal soil drying in an unsaturated clay soil. Int. J. for Num. and Anal. Meth. in Geomechanics, 17(1), pp. 119-132.

Thomas, H. R. and Rees, S. W. (1991). A comparison of field monitored and numerically predicted moisture movement in unsaturated soil; Int. J. for Num. and Anal. Meth. in Geomechanics, 15, Issue 6, pp. 417-431.

Thorne, C. R. (1990). *Effects of vegetation on riverbank erosion and stability*. In Vegetation and Erosion: Processes and Environments, John Wiley and Sons, pp.125-144.

Tracy, F. T. (1995). 1-D, 2-D, and 3-D analytical solutions of unsaturated flow in groundwater. Journal of Hydrology, 170, pp. 199-214.

Tracy, J. C. and Marino, M. A. (1989). Solute movement through root-soil environment. Journal of Irrig. and Drainage Engineering, 115(4), pp. 608-625.

Tucker, R. L. and Poor, A. R. (1978). Field study of moisture effects on slab movements. ASCE, Journal of Geotechnical Engineering. 104(4), pp. 403-415.

Tufekcioglu, A., Raich, J. W., Isenhart, T. M. and Schultz, R. C. (1999). Fine root dynamics, coarse root biomass, root distribution, and soil respiration in a multispecies riparian buffer in Central Iowa. USA. Agroforestry Systems, 44, pp. 163-174.

van Dam, J. C., Wösten, J. H. M. and Nemes, A. (1996). Unsaturated soil water movement in hysteretic and water repellent field soils. Journal of Hydrology, Volume 184, Issues 3-4, pp. 153-173.

Veihmeyer, F. J. and Hendrickson, A. H. (1955). Does transpiration decrease as the soil moisture decreases? Transactions of American Geophysical Union, 36, pp. 425-448.

Verma, P., George, K. V., Singh, H. V., Mathew, T. P. and Singh, R. N. (2004). Simulating water movement and its uptake by plant roots in unsaturated zones. Intern. J. Environ. Studies, Vol. 61(1), pp. 39-48.

Vrugt, J. A., Hopmans, J. W. and Simunek, J. (2001a). Calibration of two-dimensional root water-uptake model. Soil Sci. Soc. Am. J. 65(4), pp. 1027-1037.

Vrugt, J. A., Hopmans, J. W. and Simunek, J. (2001b). One , two and three-dimensional root water-uptake function for transient modeling. Water Resource Res. 37(10), pp. 2457-2470.

Wang, E. and Smith, C. J. (2004). Modelling the growth and water uptake function of plant root systems: A review, Aust. J. Agric. Res. 55, pp. 501-523.

Ward, W. H. (1953). Soil movements and weather. *Proc. 3rd Int. Conf. Soil Mech.*, Zurich, 2, pp. 477-481.

Ward, R. C. (1975). *Principles of hydrology*. 2nd Edition, London McGraw-Hill UK.

Warrick, A. W. (1975). Analytical solutions to the one-dimensional linearized moisture flow equation for arbitrary input, Soil Sci. 120(2), pp. 79-84.

Wesseldine, M. A. (1982). House foundation failures due to clay shrinkage caused by gum trees. Transactions, Inst. of Professional Engrs, N.Z., March, CE9(1).

Whisler, F. D., Klute, A. and Millington, R. J. (1968). Analysis of steady stste evapotranspiration from a soil column. Soil Sci. Soc. Am. J. 32, pp. 167-174.

Wilcock, D. N. and Essery, C. I. (1984). Infiltration Measurement in a Small Lowland Catchment. Journal of Hydrology, 74, pp. 191-20.

Wu, J., Zhang, R. and Gui S. (1999). Modeling soil water movement with water uptake by roots. Plant and Soil, pp. 215.

Xu, F. Y. (2004). Fractal approach to unsaturated shear strength. Journal of the Geotech. and Geoenvironmental Engineering (ASCE), 130(3), pp. 264-273.

Yeagher, A. F. (1935). Root systems of certain trees and shrubs grown on prairie soils. Journal of Agricultural Research 51(12), pp. 1085-1092.

Yeh, T. -C. J., Gelhar, L. W. and Gutjahr, A. L. (1985). Stochastic analysis of unsaturated flow in heterogeneous soils 3: Observations and applications. Water Resources Research, 21 (4), pp. 465-471.

Yong, R. N. and Warkentin, B. P. (1974). *Soil properties and behavior*. Amsterdam: Elsevier Publishing Company.

Zapata, C. E., Houston, W. N., Houston, S. L. and Walsh, K. D. (2000). *Soil-water characteristic curve variability*. In: Shackeford *et al*. (eds.) *Advances in unsaturated geotechnics*. GEO-Institute, ASCE, U.S.A. pp. 84-124.

Zhang, L. L., Fredlund, D. G., Zhang, L. M. and Tang, W. H. (2004). Numerical study of soil conditions under which matric suction can be maintained. Can. Geotech. J. 41, pp. 569-582.

Zhuang, J., Nakayama, K., Yu, G. R. and Urushisaki, T. (2001). Estimation of root water uptake of maize an ecophysiological perspective. Field Crops Research, 69, pp. 201-213.

Zienkiewicz, O. C. and Taylor, R. L. (1989). *The Finite Element Method.* London: McGraw-Hill Book Company.

Zienkiewicz, O. C. (1977). *The Finite Element Methods*. London: McGraw-Hill.