



THE IMPACT OF HUMIDITY ON THE TEMPERATURE OF LOAMY SOIL IN THE PRESENCE OF MAGNETIC FIELD WITH PERIODIC BOUNDARY CONDITION

Olaleye O. A.^{1*}, Olalude G. A.², Adewoye S. K.³, Bamigboye J. S.⁴ and Amola B. A.⁵

^{1, 2, 4, 5} Department of Statistics, the Federal Polytechnic, Ede.

³Department of Science and Social Sciences, Directorate of General Studies, Osun State Polytechnic, Iree.

* Correspondence: hezekiaholaleye@gmail.com

Abstract: This study deployed a mathematical model to evaluate the impact of humidity on the temperature of magnetically treated loamy soil in a controlled laboratory environment. Heat transferred equations were used to model the problem. A sample of loamy soil was taken to be magnetically treated and then subjected to a range of relative humidity levels. The solution to the energy equation was done analytically, while the numerical solution was done and displayed on graphs by employing MATLAB software for better study. Results show that humidity had a significant effect on the temperature of the magnetically treated loamy soil, with an increase in relative humidity levels leading to an increase in the temperature of the soil sample. This thus suggests potential applications in controlling soil temperature for agricultural purposes. Further research is needed to evaluate the effects of other environmental factors on soil temperature and the potential applications of magnetic soil treatment in agricultural settings.

Keywords: "Boundary condition", "humidity", "loamy soil", "magnetization", "MATLAB software", "temperature".

INTRODUCTION

Humidity and soil temperature are important factors for determining the rate of growth for many plants. Temperature on its own is one of the most important environmental factors affecting the growth, developments, and performance of plants. Temperature can influence the rate of photosynthesis, respiration and transpiration, leading to increased leaf growth, increased stem elongation, and increased plant biomass production. It can affect metabolism, growth duration, germination, flowering and yield. Temperature is a major factor in plant growth because of its effect on photosynthesis. Temperature can also affect the number of stomata on leaves, and hence the rate of transpiration. At higher temperatures, the number of stomata increases leading to increase transpiration and increased uptake of water and nutrients from the soil.

Humidity has several advantages on plant growth, including increased nutrient and water absorption, longer lasting flower petals, increased carbohydrate production, better pest resistance, and reduced plant stress. These advantages have been studied through experiments in controlled environments, as well as in natural habitats. Plants absorb essential nutrients such as nitrogen, sulphur and phosphorus more efficiently when the air is humid. This is mainly due to the fact that the moist in the air helps dissolve these nutrients and make them more accessible to the plant. Humid conditions also make it easier for plants to absorb water, which is essential for their growth and development.

Alabison *et al* (2020) explored ground temperature fluctuations applying varying suction velocity with convective boundary condition. Their results showed the variation in the temperature of the soil at various levels of depth. More existing related literature include Olaleye *et al* (2019), Olaleye *et al* (2021), Akinpelu *et al* (2020) among host of others.

The present study investigates the relationship between these two variables (humidity and soil temperature) in the presence of a magnetic field. The primary objective was to develop a mathematical model that could accurately predict the temperature of loamy soil under different levels of humidity in the presence of a magnetic field.

MATHEMATICAL FORMULATION

A mathematical model developed to form the governing equations with some relevant assumptions structured to fit in to the condition under which the flow occurred. The model would then be used to analyze the interaction between humidity and magnetic field, and how the emerging variables influence the temperature of the loamy soil. The model used for the study was based on the heat transfer equation and the magnetic field equation. The flow was assumed to be unsteady, making it time dependent as well as soil's depth dependent. The radiation comes from solar source in line with gravity. Deploying Boussinesq's approximations, the governing equations are modelled as below.

CONTINUITY EQUATION

$$\frac{\partial w'}{\partial z'} = 0 \quad (1)$$

ENERGY EQUATION

$$\rho C_p \frac{\partial T'}{\partial t'} + \rho C_p w' \frac{\partial T'}{\partial z'} = k \frac{\partial^2 T'}{\partial z'^2} - \frac{\partial q'_r}{\partial z'} + (\sigma B_0^2 w'^2) + Q_0 (T' - T'_\infty) \quad (2)$$

Subject to:

$$T' = T'_\infty + (T'_w - T'_\infty) \left\{ 1 + \gamma \sin \left(\frac{\pi t'}{L} \right) \right\} \quad \text{at soil's surface (i.e. } z' = 0) \quad (3)$$

$$T' \rightarrow T'_\infty \quad \text{as soil's depth increases for an indefinite period (i.e. } z' \rightarrow \infty) \quad (4)$$

Bringing in the standardized dimesionless parameters:

$$w = \frac{t' w_0^2}{t}, \quad \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty}, \quad z = \frac{w_0 z'}{w}, \quad t = \frac{t'}{L}, \quad n = \frac{w n'}{w_0^2} \quad (5)$$

Moreover, consequent to Mohammed (2013), time varying suction velocity is adopted:

$$w' = -w_0 (1 + \varepsilon A e^{n't'}) \quad (6)$$

Soil is enthralling heat from sun. Therefore, following Akinpelu *et al* (2020), heat flux is certain as:

$$\frac{\partial q'_r}{\partial z'} = 4\alpha^2 T' - 4\alpha^2 T'_\infty \quad (7)$$

Besides, connecting to Akinpelu *et al* (2016), considering wavering with time, thermal conductivity is specified as:

$$k = \zeta_0 + \zeta_0 \mu t \quad (8)$$

Putting equations (5) through (8) into (2):

$$\frac{\partial \theta}{\partial t} - (1 + \varepsilon A e^{nt}) \frac{\partial \theta}{\partial z} = \left(\frac{1}{P_r} \right) \frac{\partial^2 \theta}{\partial z^2} + \left(\frac{\mu t}{P_r} \right) \frac{\partial^2 \theta}{\partial z^2} - R^2 + (Ha)^2 Ec + Q\theta \quad (9)$$

where,

$$P_r = \frac{w \rho C_p}{\zeta_0} \quad (\text{Prandtl number})$$

$$Q = \frac{Q_0 w}{w_0^2 \rho C_p} \quad (\text{internal heat})$$

$$R^2 = \frac{4w\alpha^2\theta}{w_0^2 \rho C_p} \quad (\text{radiation parameter})$$

$$Ha = (B_0) \left(\sqrt{\frac{\sigma}{\rho}} \right) \quad (\text{Hartman number})$$

$$Ec = \frac{w^3}{w_0^2 C_p (T_w^* - T_\infty^*)} \quad (\text{Eckert number})$$

Also, substituting equation (5) into equation (3) and (4), the boundary conditions became:

$$\theta = 1 + \gamma \sin(\pi t) \quad \text{at} \quad z = 0 \quad (10)$$

$$\theta \rightarrow 0 \quad \text{as} \quad z \rightarrow \infty \quad (11)$$

METHOD OF SOLUTION

Adopting technique of perturbation to shrink equation (9) to O.D.E. as applied by Nwaigwe (2010), implicit solution is specified as below:

$$\theta(z, t) = \theta_0 + \varepsilon A e^{nt} \theta_1 + o(\varepsilon^2 A^2) + \dots \quad (12)$$

But $\varepsilon A \ll 1$, thus the higher order terms of εA is negligible.

Then, putting equation (12) & its derivatives into equation (9), and taking order of $(\varepsilon A)^0$ and εA :

$$\frac{d^2 \theta_0}{dz^2} + \Phi \frac{d\theta_0}{dz} + \Phi Q \theta_0 = \Phi R^2 - \Phi (Ha)^2 Ec \quad (13)$$

$$\frac{d^2 \theta_1}{dz^2} + \Phi \frac{d\theta_1}{dz} + \Phi (Q - n) \theta_1 = -\Phi \frac{d\theta_0}{dz} \quad (14)$$

Moreso, revising equations (10) & (11) using equation (12);

$$\theta_0 = 1 + \gamma \sin(\pi t) \quad \theta_1 = 0 \quad \text{at} \quad z = 0 \quad (15)$$

$$\theta_0 \rightarrow 0, \quad \theta_1 \rightarrow 0 \quad \text{as} \quad z \rightarrow \infty \quad (16)$$

Equations (13) & (14) subjected to (15) & (16), the ambient soil temperature basically became;

$$\theta = C_1 e^{m_1 z} + C_2 e^{m_2 z} + C_3 + \varepsilon A e^{nt} (C_4 e^{m_3 z} + C_5 e^{m_4 z} + C_6 e^{m_2 z}) \quad (17)$$

where,

$$\Phi = P_r (1 + \mu t)^{-1}$$

$$m_1 = -\frac{\Phi}{2} + \sqrt{\frac{\Phi^2}{4} - \Phi Q}$$

$$m_2 = -\left(\frac{\Phi}{2} + \sqrt{\frac{\Phi^2}{4} - \Phi Q} \right)$$

$$m_3 = -\frac{\Phi}{2} + \sqrt{\frac{\Phi^2}{4} - \Phi(Q-n)}$$

$$m_4 = -\left(\frac{\Phi}{2} + \sqrt{\frac{\Phi^2}{4} - \Phi(Q-n)}\right)$$

$$C_1 = 0$$

$$C_2 = 1 + \gamma \sin(\pi t)$$

$$C_3 = \frac{R^2 - (Ha)^2 Ec}{Q}$$

$$C_4 = 0$$

$$C_5 = -C_6$$

$$C_6 = \frac{-\Phi C_2 m_2}{m_2^2 + \Phi m_2 + \Phi(Q-n)}$$

RESULTS AND DISCUSSION

As of a experimental setup where measurement of the soils temperature under varying humidities and varying magnetic field strengths were put in place, the temperature of the soil was monitored throughout the experiment. In addition, mathematical model was developed using heat transferred equations and the data obtained from the experiment were put inside the model and graphed using Matlab software visual study of the impact of the factors on the soil's temperature (taking into account the interactions between humidity, magnetic field strength and soil temperature).

Equation (17) served as a model that the physical factors were scrutinized. Soil type used was loam which thermo-physical properties were specified in table 1. The factors concerned comprise radiation parameter, thermal conductivity, primordial heat & Prandtl number. Matlab software was set up to put on view the results.

Likewise, subsequent to some accessible works similar to that of Mohammed (2013), preset values on table 2 were utilized for the study save/otherwise declared.

Table 1: Loam soil Thermo-physical property (Abu-Hamdeh and Reeder, 2000)

Soil	Thermal Conductivity (W/m K)	Moisture Content (%)
Loam	0.29	1.4
Loam	0.76	21.2

Table 2: Preset values of parameters concerned

P _r	R	Q	Ha	Ec	μ	t	A	n	E	γ
0.71	0.10	0.01	1.00	0.01	0.29	0.1	0.5	1.00	0.01	1.0

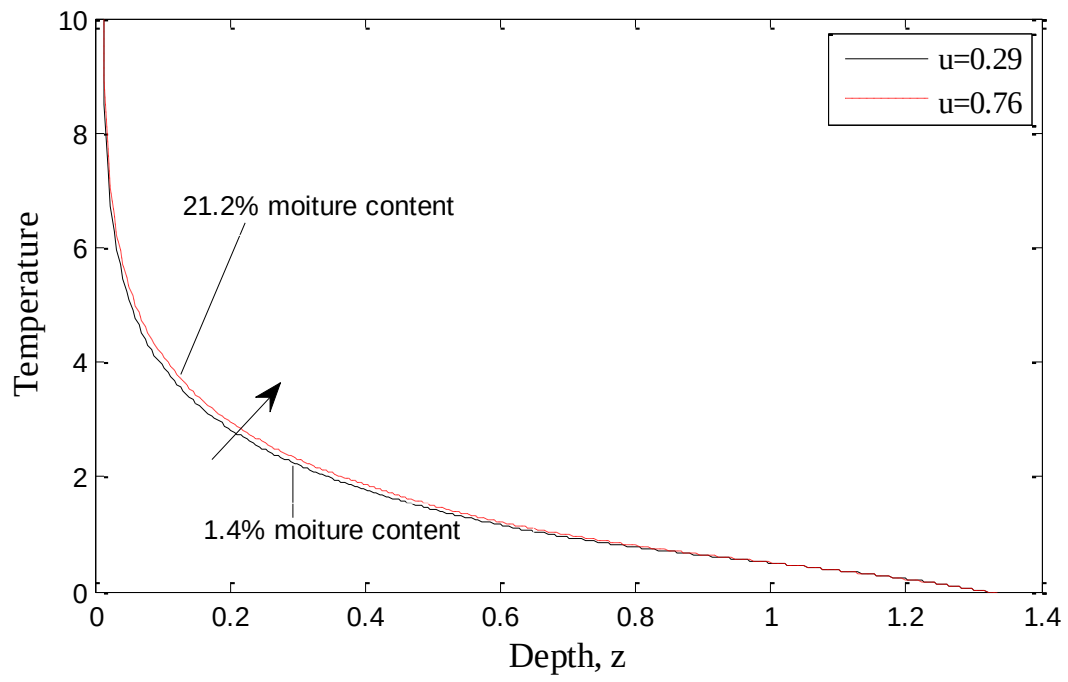


Figure 1: Humidity impact on Loam soil temperature as all other parameters kept constant

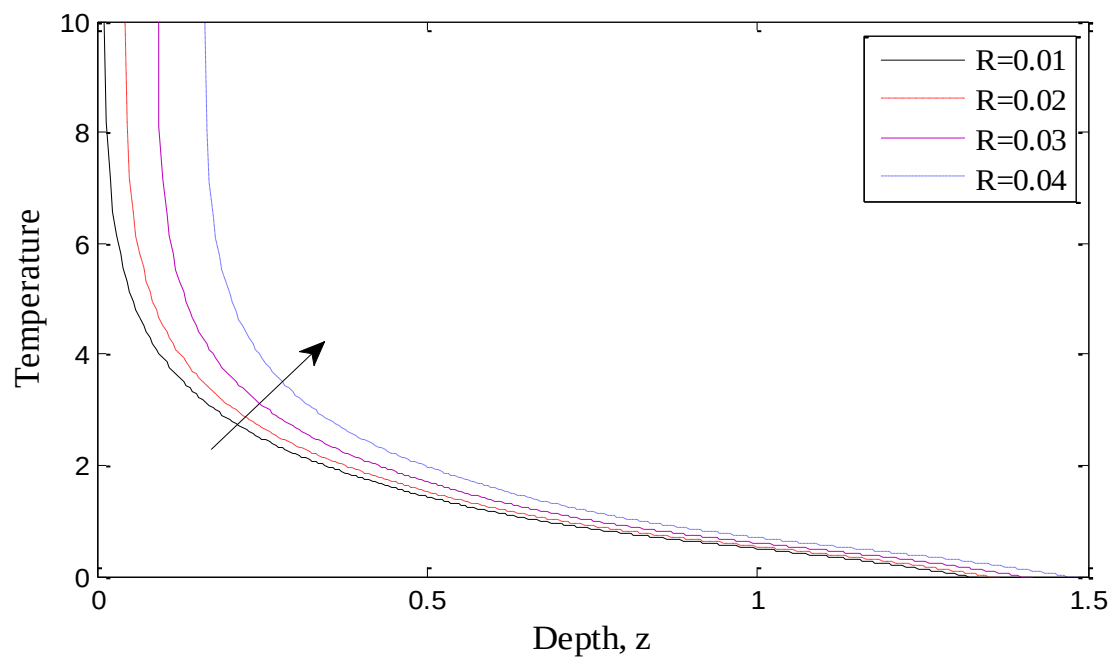


Figure 2: Radiation impact on Loam soil temperature at constant humidity

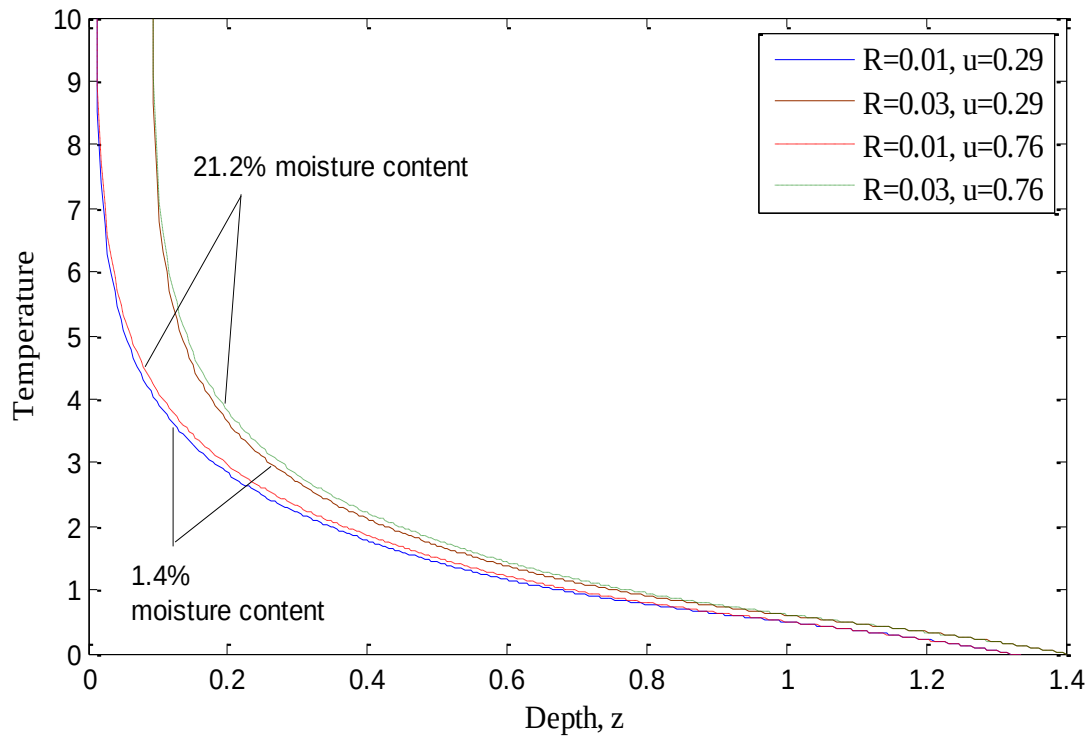


Figure 3: Humidity and Radiation impact on Loam soil temperature

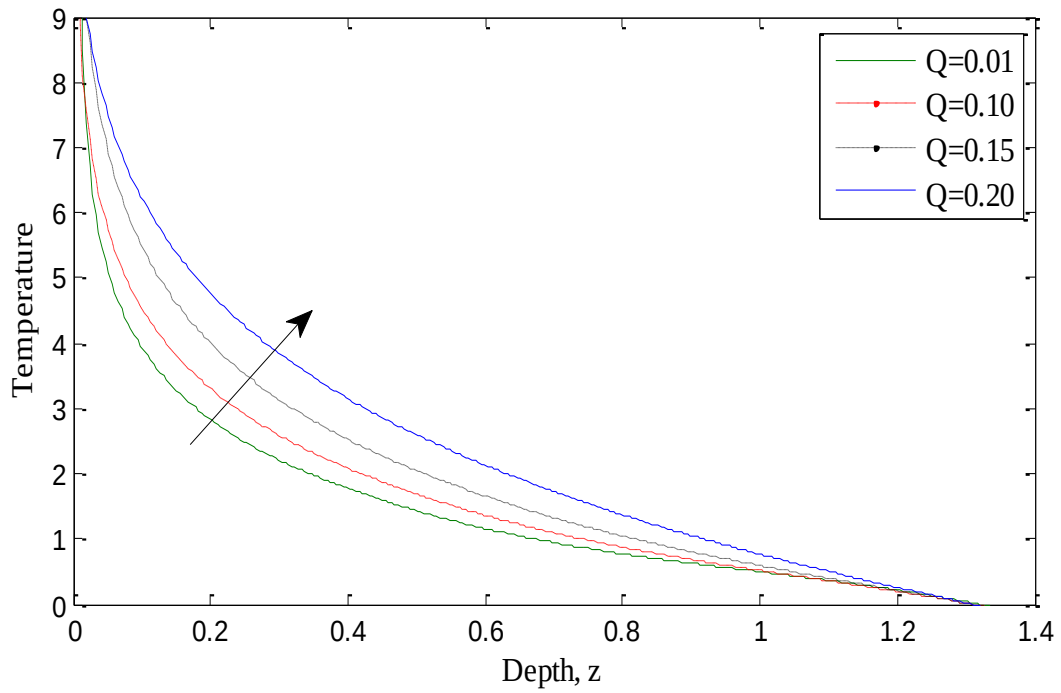


Figure 4: Internal heat impact on Loam soil temperature at constant humidity

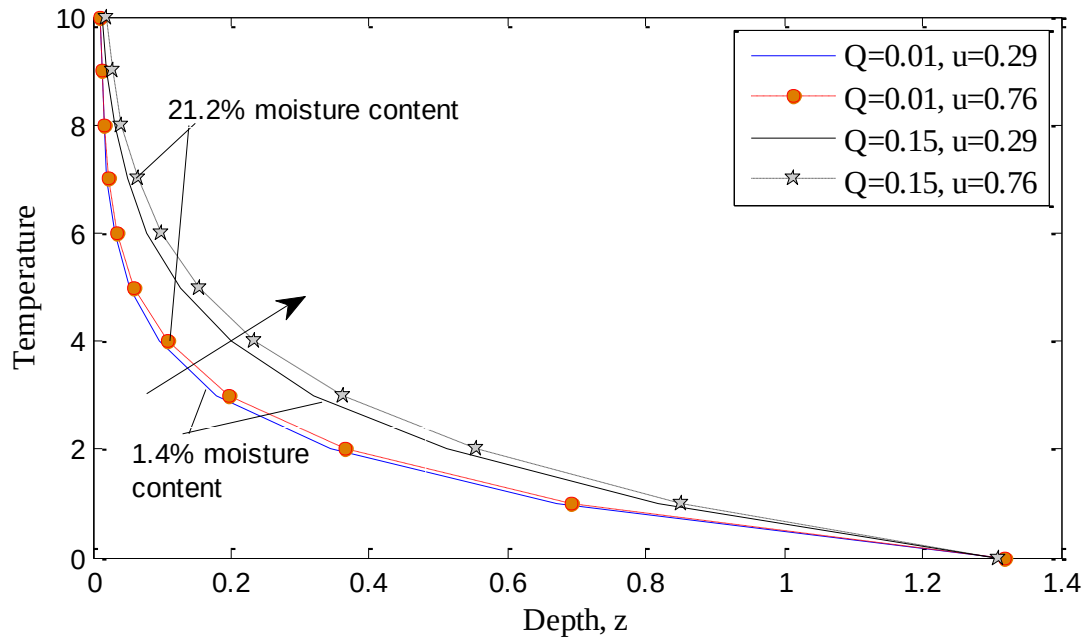


Figure 5: Humidity and Internal heat impact on Loam soil temperature

CONCLUSION

The study of the impact of humidity on the temperature of loamy soil in the presence of magnetic field with periodic boundary condition was carried out. A mathematical model developed from the experiment predicts the soil temperature under different levels of humidity and magnetic field strengths. The results of the experiment showed that the temperature of the loamy soil increased with increasing humidity in the presence of the magnetic field.

The results of the model simulations suggest that humidity has strong impact on the temperature of the loamy soil and that this effect is amplified by the presence of a magnetic field. Furthermore, the model indicated that the effect of the humidity and the magnetic field on the temperature of the loamy soil is generally nonlinear. In conclusion, this study adds to the knowledge base on the interactions between humidity, magnetic fields, and temperature in soils.

These findings have implications for understanding how the environment affects the temperature of loamy soil in the presence of a magnetic field and optimize the design of geotechnical systems. Overall, the study provides evidence that the presence of a magnetic field can influence the temperature of loamy soil in response to changing levels of humidity. Moreover, the mathematical model developed can be used by researchers to accurately forecast the temperature of loamy soil under different conditions.

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