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Study of variation of Magnetic Field around a Palm Tree Using Smartphone Magnetometers: Influence of Height and Distance

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Abstract

In this study, the Phyphox software and smartphone magnetometers are used to examine the variation of magnetic fields around the palm tree. In order to minimize external influence, measurements were made along the X, Y, and Z axes at various heights (from the root to 150 cm) and distances (0–4 cm) from the trunk. No people were in the vicinity, and other mobile devices were not allowed in order to prevent disruptions and provide a thorough spatial profile of the magnetic field. Results show that species, root structure, and temperature all affect the strength of the magnetic fields, which are higher at lower altitudes and nearer to the tree. This portable, affordable technique demonstrates the potential of cellphones for environmental, ecological, and geophysical research while providing fresh perspectives on how electromagnetic fields interact with plants. This manuscript provides significant new understandings of the complex relationships between plants and electromagnetic fields. Overall, improvements in accuracy, recalculation time, and computing cost were achieved with favorable outcomes.

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Introduction

The widespread usage of smart phones has led to the emergence of a new class of services known as location-based services (LBS), which mostly rely on location data. Depending on the user's location, which is determined via mobile devices and communication networks, LBS are offered through mobile apps (Ashraf *et al.,* 2018). Conducting experiments and analyzing data can be useful methods for creating a collaborative and interactive environment. Mobile devices offer hundreds of millions of applications to help users carry out daily tasks.

In our research, we have used magnetometer sensor, which is used to measure magnetic fields around the trees. The magnetic field intensity changes when a smart phone is rotated around its axis. Essentially, it investigates how the strength of the magnetic field fluctuates as the phone is turned (Ouyang and Abed-Meraim, 2022). The change in the strength of the magnetic field affects plants (Maffei, 2014). The study emphasizes the paucity of mathematical knowledge in this sector and admits the complexity of the theoretical basis of the effect of magnetic fields on plant growth (Da Silva and Dobránszki, 2015). Electromagnetic fields (EMFs) can help plants deal with different environmental challenges like drought, salinity, ultraviolet light, heavy metals, high temperatures, and pathogens. The trees have a magnetic property around them, due to which the presence of a magnetic field is observed around the tree. After the investigation of the magnetic property in trees, studies revealed some factors and hypothesis behind it like trees are formed by a magnetite crystal inside their tissues. The understanding of magnetite in trees is an area of ongoing research. The magnetic field around the trees is affected by many factors, including the magnetic field of man-made sources like electrical equipment, mobile phone base stations, mobile phones, etc. To understand the complexities of these magnetic fields, consider the physiological processes of tees, such as water uptake, growth pattern, and response to environmental stimuli. Students' interest can be piqued by using their own resources and measuring everyday phenomena. Accurate data analysis can foster scientific thinking and offer an excellent opportunity for inquiry-based learning. (Escobar *et al*., 2018). The majority of which are free that enable us to display measurements on the smart phone screen, store these measurements, and even graph the findings, then these sensors enable us to do direct measurements of physical magnitudes. The quality of the yield varies as the attractive magnetic field penetrates them, and the lobby sensor is used to detect the strength of the magnetic field. The component of the magnetic field in each direction over spatial orientation of the device is measured by vector magnetometers in mobile devices (Odenwald, 2022). The dependency of a magnet's output on its distance from another magnet using the magnetic sensor found in smart phones. The results will be compared to theoretical predictions (Garde, 2015). The majority of gadgets come equipped with inbuilt sensors that produce raw data with excellent precision and are helpful for tracking environmental changes or for monitoring three-dimensional motion or placement. (Sampaio *et al.,* 2023). The traffic on the road is likely contributing to the presence of magnetic particles in the environment and that trees facing away from the road tend to collect more of these particles (Kletetschka *et al.,* 2003). "Phyphox" provides a standard webpage with code on it that periodically retrieves the most recent information from the application. The phyphox technique differs in that it just streams the raw experimental data. The software functions as a web server in theory, and all that's needed for the distant device to connect to it is a contemporary web browser. Phyphox provides a standard webpage with code on it that periodically retrieves the most recent information from the application. The measured data may also be displayed to an audience using a laptop and a projector, utilizing the whole screen instead of only the phone's portrait format, because the data representation also suits the target device's screen format (Staacks, 2018). Among these are real-time collaborative experiments with hundreds of undergraduate university students in a lecture hall and a real-time collaborative experiment with users worldwide in a casual learning environment. (Staacks *et al.,* 2022).

In order to ensure that students develop the cognitive abilities necessary for the development of scientific concepts, a reform in the practices of teaching, learning, and evaluation of the sciences in general and physics in particular is needed. The EMFs ranging from very low to high frequencies have been seen to improve various aspects of plant health, such as seed vigor, growth, water uptake, photosynthesis, biomass production, and the production of protective substances. It helps to reduce harmful free radicals and oxidative stress in plants by activating their defense mechanisms (De Souza-Torres, 2021). Magnetization is a type of iron oxide that is naturally found on the Earth. Magnetite has a cubic crystal structure, and the placement of iron ions contributes to its magnetic property. Its color is black or brownish-black, and its appearance is opaque. Magnetization has been found in various living organisms, like bacteria, mammals, and birds. In trees and plants generally, it is present in the form of magnetite nanoparticles (Aravena *et al.,* 2022). Magnetite plays an important role in trees, due to which trees sense the Earth's magnetic field. Magneto reception is used to optimize the growth direction in response to environmental cues. The "radical-pair mechanism" and the "ion cyclotron resonance" mechanism are the two methods for magneto reception in a theoretical foundation for upcoming studies in the area of plant magneto reception (Maffei, 2022). These magnetic materials can influence the magnetic properties of soils and sediments. This research proposes a technique for gathering tree measurement parameters using a range of high-precision sensors and personal smart space fusion (Fan *et al.,* 2020). The idea of utilizing smartphone sensors for physics experiments has gained popularity among science educators. Because most instructors and students get easy access to these gadgets, experiments may be set up for little to no money. The novelty of utilizing their own devices in a different way can pique students' interest and motivate them (Staacks *et al.,* 2019). This might involve activities like using spreadsheet software like excel to perform numerical integration or determining the time code of an event that has been recorded. In addition to these advantages, the data may be downloaded straight from the web browser. If the students need to analyze the data further, it may be downloaded right away to the computer they'll be using for the subsequent stages. The only need is that both devices must be connected to the same network, which is also true for the majority of video streaming apps. (Staacks *et al.,* 2018). In this article, we describe a new network interface for the education-focused sensor app "phyphox," providing examples of how this new interface has been applied in various learning contexts. Standard geophysical field approach magnetic surveying is widely applied to many different fields. The fundamental concept of the magnetic technique is the measurement of changes in the Earth's magnetic field and their correlation with things buried or subterranean geology. We just provide a quick overview of the crucial context here (Tronicke, 2018). The research done in the last 30 years represents that EMFs have harmed many species, like mammals, birds, fish, amphibians, reptiles, insects, plants, and trees. Even at intensities comparable to current ambient levels, these EMFs cause significant damage to these creatures (Balmorí, 2022).

Materials and methods

The palm tree is generally available in all nurseries, and houses. The palm tree is available in our location, we were able to carry out the experiment effectively. The tall, thin trunks and big leaves of palm trees make it easier to study variations in the magnetic field in an expected and regulated way. By concentrating on only one specie, the variable is reduced and the impact of the magnetic field on trees is isolated. A smartphone with a magnetometer application is all that is required to complete the experiment. Samsung S20 Fe (5G) smartphone is used in this experiment. Phyphox application is integrated with calibration feature which make easy to get readings. A measuring tape is used to mark points at different heights. In order to maintain systematic and uniform measurements throughout the experiment, we have marked heights at regular intervals. The authors have selected the distance ranges 0 to 4 cm away from palm tree trunk along X, Y, Z-axis this enables us to understand that in how much area magnetic field gets affected. And we have selected height range of 0-60 cm, because at lower height more variation in magnetic field is shown whereas if distance is increased results are getting more fluctuated.

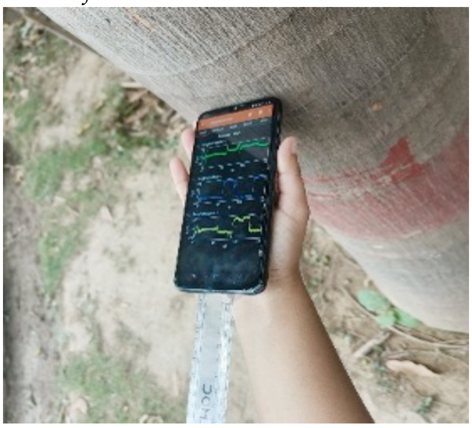
Figure 1

Setup of smartphone while taking reading along Palm tree

(a)Palm tree

(b)Smartphone along x-axis of Palm tree

(c)Smartphone along Y-axis of Palm tree



(d)Smartphone along Z-axis of Palm tree

Three magnetometers—one for each spatial direction—are included on the smart phone. Each sensor is measured separately in order to reduce the possibility of any of the sensors being mis calibrated. Accurate data measurement reduces the influence of external electromagnetic interference. Only smartphones with measuring apps were utilized; other mobile devices were not allowed in the area. There were no people in the area to prevent any disruptions. The precision and dependability of our data were guaranteed by these measures.

In this manuscript, the experiment is performed to determine the variation of magnetic field around the tree. The variation is observed around the palm tree situated in the campus of Graphic Era Hill University Dehradun. The presence of external electronic gadgets is more in day time, so this work was done in day time in between the working hours of the university. The amplitude of magnetic field is varied with respect to time. A smartphone with a magnetometer application is required to complete the experiment. Samsung S20 Fe (5G) smartphone is used in this experiment. Phyphox application is integrated with calibration feature which make easy to get readings. To collect useful data for the experiment, we have made sure that the magnetometer readings are precise and consistent through the calibration procedure. A measuring tape is used to mark points at different heights. In order to maintain systematic and uniform measurements throughout the experiment, we have marked heights at regular intervals. We have taken the readings at the height from the root of the tree to 60 cm along the x, y and z axes. The data is collected with the combined effect of magnetic fields of tree and earth. The magnetic field is also affected with the presence of human beings and electronic gadgets nearby the tree. The mobile application is used to collect and analyze the data.

Three magnetometers, one for each spatial direction, are included on the smart phone. Each sensor is measured separately in order to reduce the possibility of any of the sensors being mis calibrated. The measurement of the magnetic field around the tree is done by placing the smart phone next to the tree trunk at its root. It should make sure that the magnetometer sensor is unobstructed. Hold the smart phone steadily while ensuring that the magnetometer is pointed in the direction of the tree trunk. Play the "Start" button in Phyphox app before collecting the data at the root of the tree. At this height, take the measurement of magnetic field along the x-axis, y-axis, and z-axis at 1cm to 4cm away from the trunk. Data for magnetic field is captured by Phyphox app at the chosen height. For maximum accuracy and to account for any variations in the magnetic field, repeat the experiment 4 times for each reading. Once the measurements at the chosen height have been taken, press the "Stop" button. After that move the smart phone along the tree stem to a height of 15 cm, to capture magnetic field data at this increased height, repeat the same procedure by keeping the smart phone stable along all axes. Now carry out the same procedure for every height. By changing distance from the trunk along the x-axis, y-axis, and z-axis and use the same technique to take measurements at different heights. Download the recorded data in an MS Excel sheet and plot the graph. After plotting the graphs, analyses the variation in magnetic field intensity along the tree trunk at different distances and at different heights. Determine the link between height and variance in the magnetic field surrounding the tree by examining patterns or trends in the data.

Results

For a short period of time, the observations of magnetic fields are taken at the root of the tree along the X, Y, and Z-axis. Figure 2(a) shows observations of magnetic fields taken along the X-axis over time. In the graph, we have two peaks of maximum intensities, which are at 0 cm and 4 cm away from the tree. The minimum intensities are observed at 1cm and 2cm away from the tree. The graphs show the variable nature due to the presence of man-made electromagnetic waves in the environment. The variation of the magnetic field along the Y-axis shown in Figure 2(b). The graph clearly shows that the maximum intensity occurred 3 cm away from the tree. At 1 cm and 2 cm away, the magnetic field is minimum. In Figure 2(c), the variation of the magnetic field along the Z-axis is shown for short time. The maximum and minimum intensity of the magnetic field occur at 3 cm and 0 cm away from the tree surface, respectively.

Figure 3(a) represents the variation of the magnetic field at 15 cm along the X-axis over time. It is found that for this short interval of time, the maximum and minimum intensities both occurred 4 cm away from the tree. Due to the presence of an external magnetic field in the environment at every instant, the intensity of the magnetic field is changing. In Figure 3(b) the variation of the magnetic field is shown along the Y-axis. For this short time interval, the magnetic field intensity at 1cm is very high compared to the intensities at 0 cm, 2 cm, 3 cm, and 4 cm. The variation of the magnetic field along the Z-axis over time is shown in Figure 3(c). The maximum and minimum intensities of magnetic field are observed at 1cm and 3cm away from the tree, respectively. It can be seen from the graph that after 0.1 sec, the variation is very low at 0 cm to 4 cm distance from the tree, which shows the presence of an external magnetic field around the tree. The y-axis graph shows the variation in magnetic field in vertical direction above the roots. This variation is due to several factors like moisture content of the soil, depth of roots. These graphs make very simple to study 3-D nature of distribution of magnetic field around trees.

Figure 4(a) shows how the magnetic field varies along the X-axis at a height of 30 cm above the Earth's surface. It is observed that the maximum and minimum fluctuations of the magnetic field are obtained at 3 cm and 4 cm distance from the tree. Due to the influence of external magnetic fields in the environment, the fluctuations in the intensity of the magnetic field are random in nature. The variation of the magnetic field along the Y-axis is shown in Figure 4(b). Usually, the magnetic field intensity decreases with increasing distance from the source, but here we can see that the variations are arbitrary, which shows the presence of an external magnetic field around the tree. Figure 4(c) represents the fluctuations of the magnetic field along the Z-axis over time. The maximum and minimum variation in the magnetic field is observed at 2 cm and 0 cm away from the tree, respectively.

At 45 cm from the root the intricate structure of magnetic field is produced along x, y, z-axis. Figure 5(a), 5(b) and 5(c) shows the variation of magnetic field along the axis over time. Examine the magnetic field at 60 cm and along axis is critical because the effect of trees composition, root system, canopy density, soil quality and environmental conditions affects the reading of magnetic field. Figures 6(a), 6(b), 6(c) respectively shows the variable magnetic field along x, y, z-axis over time.

Figure 2

Measurement of magnetic field around the tree at 0 cm height (root) from the Earth surface

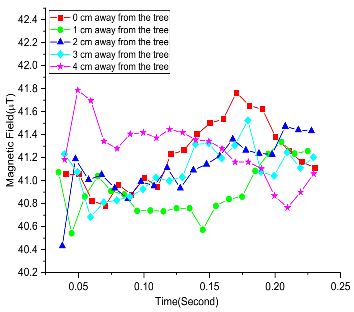


Figure 2(a): Magnetic field variation along the X-axis measured at the root level (0 cm) at distances 0–4 cm from the tree trunk over time.

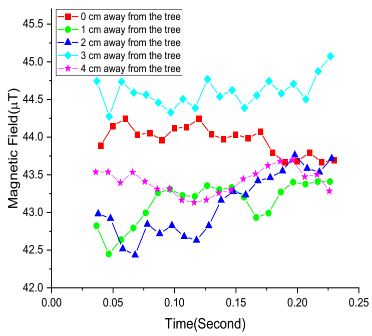


Figure 2(b): Magnetic field variation along the Y-axis measured at the root level (0 cm) at distances 0–4 cm from the tree trunk over time.

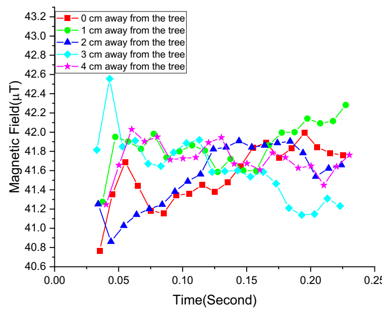


Figure 2(c): Magnetic field variation along the X-axis measured at the root level (0 cm) at distances 0–4 cm from the tree trunk over time.

Figure 3

Measurement of magnetic field around the tree at 15 cm height from the Earth surface

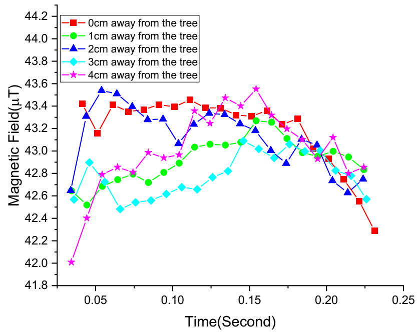


Figure 3(a): Magnetic field variation along the X-axis measured at 15 cm height from the root level at distances 0–4 cm from the tree trunk over time.

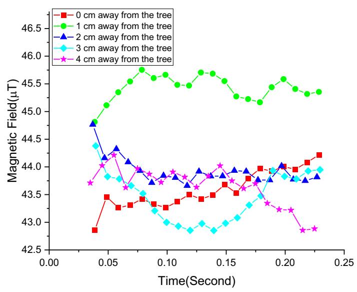


Figure 3(b): Magnetic field variation along the Y-axis measured at 15 cm height from the root level at distances 0–4 cm from the tree trunk over time.

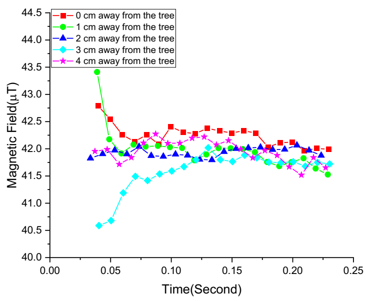


Figure 3(c): Magnetic field variation along the Z-axis measured at 15 cm height from the root level at distances 0–4 cm from the tree trunk over time.

Figure 4

Measurement of magnetic field around the tree at 30 cm height from the Earth surface

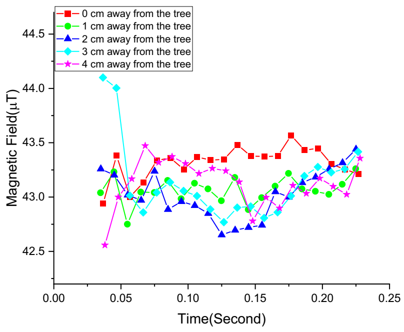


Figure 4(a): Magnetic field variation along the X-axis measured at 30 cm height from the root level at distances 0–4 cm from the tree trunk over time.

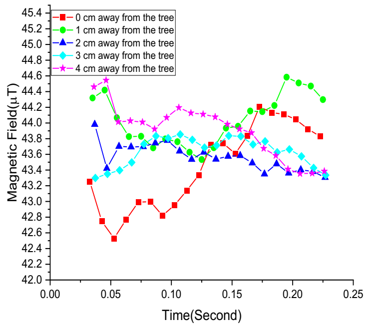


Figure 4(b): Magnetic field variation along the Y-axis measured at 30 cm height from the root level at distances 0–4 cm from the tree trunk over time.

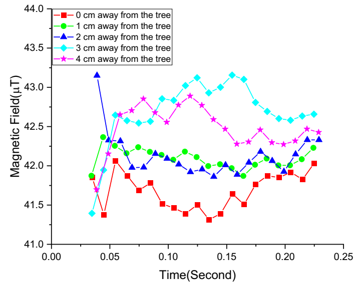


Figure 4(c): Magnetic field variation along the Z-axis measured at 30 cm height from the root level at distances 0–4 cm from the tree trunk over time.

Figure 5

Measurement of magnetic field around the tree at 45 cm height from the Earth surface

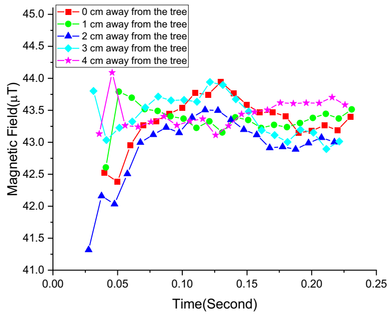


Figure 5(a): Magnetic field variation along the X-axis measured at 45 cm height from the root level at distances 0–4 cm from the tree trunk over time.

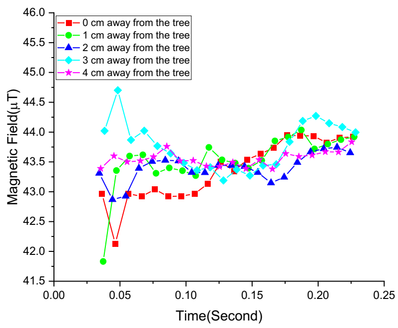


Figure 5(b): Magnetic field variation along the Y-axis measured at 45 cm height from the root level at distances 0–4 cm from the tree trunk over time.

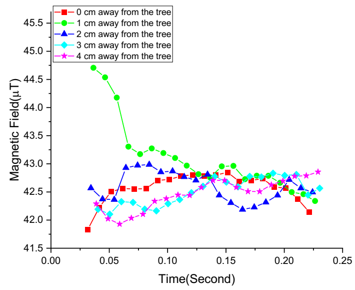


Figure 5(c): Magnetic field variation along the Z-axis measured at 45 cm height from the root level at distances 0–4 cm from the tree trunk over time.

Figure 6

Measurement of magnetic field around the tree at 60 cm height from the Earth surface

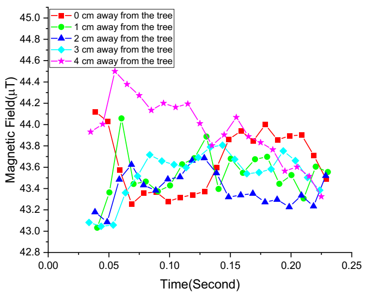


Figure 6(a): Magnetic field variation along the X-axis measured at 60 cm height from the root level at distances 0–4 cm from the tree trunk over time.

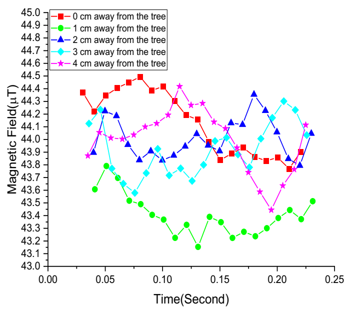


Figure 6(b): Magnetic field variation along the Y-axis measured at 60 cm height from the root level at distances 0–4 cm from the tree trunk over time.

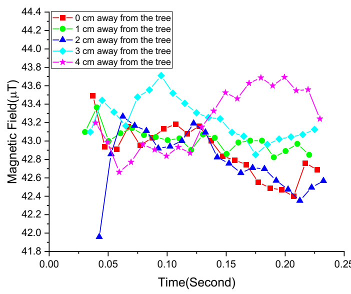


Figure 6(c): Magnetic field variation along the Z-axis measured at 60 cm height from the root level at distances 0–4 cm from the tree trunk over time.

Discussion

Magnetic field strength fluctuations can happen close to trees along the x, y, and z axis, especially at the roots. We have made measurements of the magnetic field intensity in the vicinity of a tree on the x, y, and z axis, in the range from 0 to 4 cm measuring distance from the tree surface. The observation data indicated a high degree of the magnetic field intensity randomness over such a short time slot as 0.25 seconds in all three axes. Initially, variations in the intensity of the magnetic field are shown horizontally, perpendicular to the tree stem, on the x-axis graph. This graph represents the lateral displacement of magnetic fields from the tree base and their corresponding variations. It is observed that the magnetic field in the vicinity of trees may be affected by different factors. Firstly, it is the soil's geological composition (various soil types and rocks show different levels of impact on the magnetic field). Secondly, it is the root system (roots of trees may contain magnetic materials and alter the surrounding soil). Finally, the species and age of the tree matter, since the magnetic field of the tree tissues is influenced by the content of the magnetic material present in it. It is also observed that the variation along z-axis with respect to x and y axis of the tree is very small. The amplitudes of the peaks are very low than x and y axis. But it is also observed when the observations are taken at 30 cm height from the Earth, the variation in amplitude becomes high in direction of z-axis and low in the direction of x-axis. At 60 cm height, the variation in amplitude of magnetic field is about same in all three dimensions. Obstacles, soil heterogeneity, and root dispersion are a few examples of variables that might affect variations along the x-axis.

The magnetic field intensity usually decreases with increasing distance along the x-axis, which is a horizontal extension from the source. However, localized oscillations are seen, showing patterns that deviate from expectations. These variations may be caused by magnetic materials in close proximity, structural asymmetry in the magnetic source, or other external circumstances. These results are due to modification in the surrounding medium.

Our study had some limitations. We measured magnetic field for one palm tree within a short height (up to 60 cm) and distance range (up to 4 cm) under controlled environmental conditions. The external magnetic interference and species variation were not extensively addressed. Future research should include multiple tree types, wider spatial sampling, and advanced filtering to improve result accuracy and applicability

Conclusion

The magnetic field surrounding subterranean structures, such as metallic items, roots, or rocks, can be distorted and undergo changes in strength. Variations in soil moisture content can also impact variations in magnetic field strength. The magnetic characteristics of the soil can change, and the magnetic field can fluctuate as a result of biological activity in the root zone, such as microbial activity or root development. When analysing variations in the strength of the magnetic field, it is important to take into account any equipment faults or measurement imperfections. A useful method for understanding the geographic distribution of magnetic fields surrounding trees is to use the Phyphox app to compare the graphs showing differences in magnetic field intensity along the x-, y-, and z-axes at different heights. Every axis presents a distinct viewpoint on the electromagnetic environment, exposing diverse patterns and gradients impacted by a range of variables like the distribution of roots, the composition of the soil, and the surrounding topography. In addition, the intensity of the magnetic field is also affected by environmental factors. The situation is complicated by the fact that the magnetic field is distorted by the magnetic field of the earth itself. Our goal is to show that this approach is feasible and accessible by concentrating on magnetic field differences surrounding palm tree. This approach may be modified for future environmental investigations that are more comprehensive. Using the Phyphox app, we devised a methodical strategy to maximize data collecting, guaranteeing precision and consistency in outdoor settings.

Recommendation

After analysis, the variation of magnetic fields nearby the trees, it is recommended that some additional studies are needed in order to understand what factors create a source of these fluctuations and what consequences it can have for ecological and environmental processes.

Acknowledgement

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Declaration of interest

The authors declare that there is no conflict of interests and funding source regarding this research.

Ethical Clearence

There is no requirement of ethical clearance as the experiment is not done any animal or human beings. The data is collected around the tree without any harm to the tree. The mobile application, computer software and mobile sensors are used to collect and analyse the data.

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