Effect of Environmental Factors (Relative Humidity) on Thermal Signature of Buried Objects

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Abstract: The environment in which mines are placed is extremely variable in terms of climate, vegetation, soil type, depth of ground water table, and topography. Variations in environmental conditions influence sensor performance because in general, landmine sensors exploit soil and environmental conditions to discern between mines and other objects. Little effort has been made on evaluating the environmental conditions that affect sensor performance. In this work, the effect of relative humidity on thermal signature of buried objects was examined. It was observed that relative humidity has inverse relationship to the heat emitted by the different objects. Also, it may be difficult to use this method (thermography) to detect buried objects in areas of high relative humidity as region of high relative humidity is usually characterized by little sunshine. Material identification/characterization could only possible when the relative humidity is low as this was the only period when the different buried objects had appreciable differences in thermal signature.

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1.0 Introduction

The environment in which mines are placed is extremely variable in terms of climate, vegetation, soil type, depth of ground water table, and topography. For example, the three countries that have the largest average number of mines deployed per square mile are Bosnia-Herzagovina in a temperate zone, Cambodia in the humid tropics, and Egypt in an arid desert. Variations in environmental conditions influence sensor performance because in general, landmine sensors exploit soil and environmental conditions to discern between mines and other objects. Little effort has been made on evaluating the environmental conditions that affect sensor performance. The performance of sensors based on radar and infrared imaging is expected to vary with soil and environmental conditions (Hendrickx and Borchers, 2002). Surface evaporation depends on relative humidity, temperature and wind speed. Evaporation may change surface temperature gradient (Vavilov and Klimov, 2002).

According to Pregowski *et al*, 2000, many factors which depends on mine placing environment, existing atmospheric conditions and thermal characteristics of mine itself play their role in creation of buried mine thermal image on the ground surface. Very high level of variation is typical of atmospheric conditions and this is what makes great difficulties in determination of particular parameters influence on mine detection. Detection of buried object is environment and time-dependent process.

Temperature distributions on the soil surface strongly depend on the state of the processes of mass and energy exchanges (radiation and convection, evaporation and water condensation, supply of water through precipitation and gaseous exchange). It was assumed that soil medium is homogeneous and parameters describing this medium are changeless in the whole of its volume except that they depend on soil temperature and humidity (Pregowski *et al*, 2000).

According to a report commissioned by U.S. Army corps of Engineers in 2004, the fundamental knowledge of the character of terrain (e.g. topography, vegetation types, soil types , and electromagnetic properties of the shallow subsurface) and accompanying dynamic processes that alter the properties of the terrain (predominatly season, time – of - day, and weather) are key to these models.

The deleterious impacts of varying environmental conditions even on simple mine detection technology have long been recognized.

Such effects may become even more of a factor with increasing sophistication in employing multiple sensors exploiting the full suite of spatio-temporal target/background variations (Remke et al, 2003). Sub-surface buried objects, such as landmines and archeological artifacts, and the surrounding environment constitute a complex system with variable characteristics. As a consequence, the detection and recognition of these objects may be extremely difficult (Santulli, 2009).

According to the work of (Hendrickx and Borchers, 2002), their modeling result demonstrated that soil water content regimes around landmines are strongly affected by interaction between climate, soil types, and landmine geometry. Soil water content distributions around landmines depends on local weather conditions and are very variable in time.

2.0 Materials and Method

The equipment used in this work included a Hoboware data logger and sensors (temperature and relative humidity) manufactured in the United States of America by Onset Corporation. Other materials used in this work were sourced locally; they included zinc, graphite, wood and plastic all of dimensions 12cm by 12cm surface area and thickness of 0.5cm. The experiment was carried out on a field in Lafenwa area of Abeokuta (latitude 7^{o} 3´ N and longitude 3^{o} 3´ E), Ogun State Nigeria.

This work aimed at examining the effect of relative humidity on temperature emitted by different buried objects during dry and raining Seasons in Abeokuta, South – West, Nigeria. The experiments were carried out during both dry and raining seasons in the area. One temperature sensor was laid on the soil surface to read the soil surface temperature, four temperature sensors were laid on top of the four objects (zinc, graphite, wood and plastic) buried at depth of 2cm, while the other sensor (relative humidity) was hanged up to read the relative humidity. The sampling interval is one second with logging interval of one hour.

3.0 Results and Discussion

Figure 1 shows a plot from the data, the thermal signatures of different buried objects as a function of relative humidity. The experiment was performed between 29 and 30 January 2009 which represented the dry season in the area.

Also figure 2 shows a plot from the data, the thermal signatures of different buried objects as a function of relative humidity. The experiment was performed between 4 and 5 August 2009 which represented the raining season in the area. Both experiments were performed in the same location.

The highest relative humidity during the dry season was 93.3% and this resulted in temperature emitted by the different buried objects between 26^{o}C and 28^{o}C while the lowest relative humidity was 43.5% during the same season and this resulted in heat emitted by the different buried objects between 41^{o}C and 45^{o}C. It should be noted that the lowest relative humidity does not correspond to the highest heat emitted by the different buried objects as transport of heat in the soil is not an instantaneous process.

In the case of the raining season, the highest relative humidity was 94.4% and this resulted in the temperature emitted by the different buried objects between 24^{o}C and 26^{o}C while the lowest relative humidity was 90.4% during the same season and this resulted to temperature emitted by the different buried objects between 31^{o}C and 36^{o}C.

4.0 Conclusion

It was observed that relative humidity has inverse relationship to the heat emitted by the different objects, i.e. the lower the relative humidity in an area the higher the temperature emitted by buried objects in that area and vice vasa. Also, it may be difficult to use this method (thermography) to detect buried objects in areas of high relative humidity as region of high relative humidity is usually characterized by little sunshine. In the contrary, the method will be well suited for use in areas of low relative humidity. Material identification/characterization could only possible when the relative humidity is low as this was the only period when the different buried objects had appreciable differences in thermal signature.

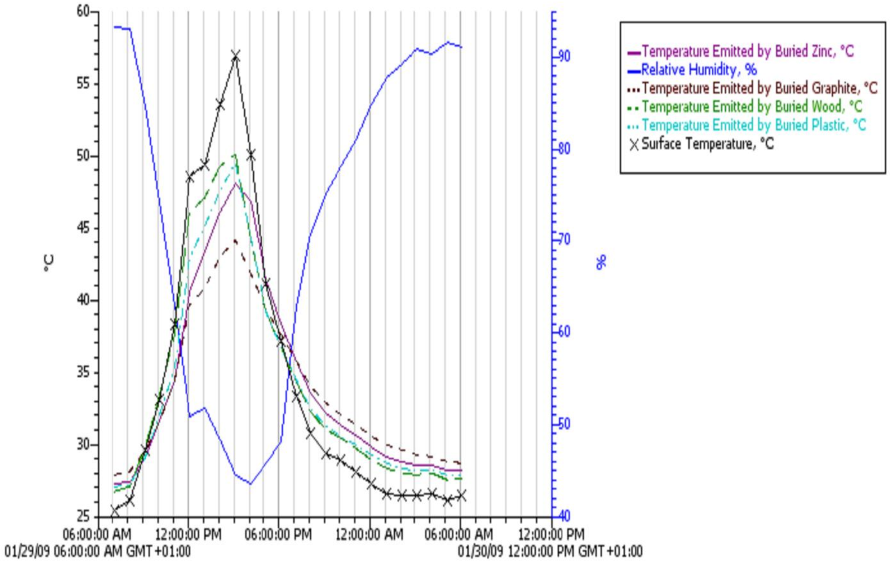

Figure 1: Effect of Relative Humidity on Temperature Emitted by Different Buried Objects during Dry Season

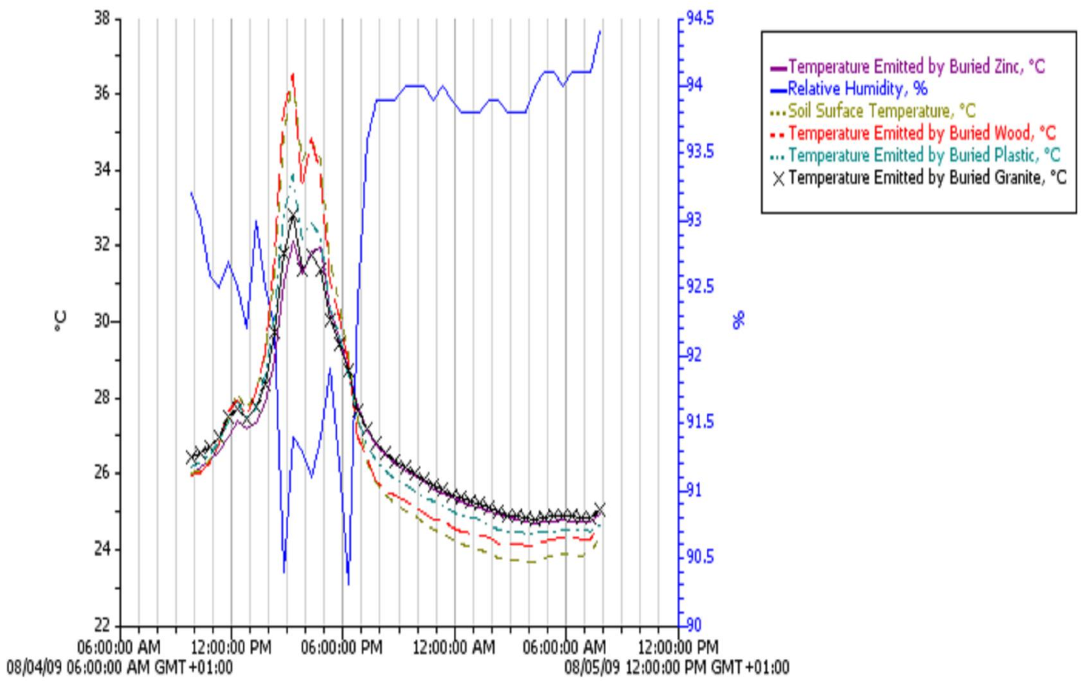

Figure 2: Effect of Relative Humidity on Temperature Emitted by Different Buried Objects during Raining Season

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