Middle-East Journal of Scientific Research 23 (8): 1780-1786, 2015
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2015.23.08.22328

Proximity Effect Analysis of Overhead High Voltage Transmission Line on Residential Communities Using Remote Sensing and Geographic Information System

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Abstract: This study is aimed to investigate the association of living near high voltage power lines which cause adverse effects on human beings due to emission of Extra Low Frequency Electromagnetic Field (ELFEMF). As power lines and towers are designed to conduct electricity over great distances, the electromagnetic properties of electricity and the magnets used in its conduction may pose certain health hazards. Many scientific evidence suggests that every day, chronic, low-intensity extremely low frequency magnetic field exposure poses a possible health risk. The theoretical calculation of electric and magnetic fields have been performed and the values are cross referenced with the basic limit set by International exposure levels of EMF. Residential communities are identified from satellite images through different image classification techniques. Based on the materials used for buildings and distance from HT lines the vulnerability on humans is analysed. The results of this study can be used as reference in future building constructions carried out near HT lines such that they minimize the health hazards.

Key words: Extremely Low Frequency (ELF) · Electromagnetic Field (EMF) · High Tension (HT) · Remote Sensing (RS) and Geographic Information System (GIS)

INTRODUCTION

The increase of power demand has increased the need for transmitting huge amount of power over long distances. Large transmission lines configurations with high voltage and current levels generate large values of electric and magnetic fields stresses which affect the human being and the nearby objects located at ground surfaces. Over the course of the last 30 years there has been a growing understanding of the effects of electric fields (EF) and magnetic fields (MF) on people. Together EFs and MFs are known as electromagnetic fields, EMFs.

Residential exposure to Electromagnetic fields (EMF) produced by Power lines are a cause of public concern. Numerous studies have investigated the correlation between occupational and residential exposures to EMF in a variety of settings and the development of cancer [1]. Many studies on the topic of electric and magnetic fields and possible health effects have been reported on over the last two decades. Some of these studies, from a scientific perspective, have been of a higher quality and have been designed and executed in more credible ways than others. In addressing consensus and conclusions drawn from this research, it makes sense to reflect on critical, scientific reviews of published research rather than to address and reflect on individual and isolated studies. Many reviews published by various organizations indicate that there is a possibility of both health and psychological disorders caused by low frequency EMF [2]. A noteworthy work on Electric and magnetic fields from overhead power lines was done by Eskom Holdings Ltd. where the impacts of high voltage transmission lines on animals, plants and human beings and the safe limits of EMF exposures have

Been discussed [3].This leads to the necessity of continuous monitoring and predictions of the EMF strength in the living environment. At the international level several organizations have developed guidelines to protect the general public from the EMF radiations [4].

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Though numerous researches have been made on determining the EMF exposure due to HT lines, researchers have not made an attempt to assess the vulnerable regions using Remote sensing technique. Recent advances in the quality of satellite imagery has improved the development of new image processing techniques for automated feature extraction and classification [5]. Genetic algorithm(GA) have been used in a variety of optimization problem especially in classifying digital datasets [6]. Genetic algorithm based classification is an accurate and time-effective method to classify satellite imagery automatically and it is used for solving a multi-dimensional unsupervised classification problem [7]. GA with proper multiobjective clustering index fitness can determine the most suitable number of clusters and cluster centres. Thus the electrical power transmission towers and vulnerable buildings are extracted from the satellite image using GA. The vulnerable regions are analysed with the help of an effective spatial entity analysis and mapping tool ArcGIS 9.3.

In this paper, urban building (impervious surface) vulnerability analysis on residential community has been carried out using Remote sensing and GIS techniques. Three intensive image analysing techniques used for Urban building Extractions, namely, Maximum Likelihood Classifier (MLC), Genetic Fuzzy Hybrid method and support vector machine techniques. Inter pixel overlapping error is a major disadvantage, when image is classified only by considering per pixel brightness value. Hence texture unit is also considered for the same objectives. Further with the help of morphology, fine turned urban feature has been derived from satellite image.

The output obtained, when GA is applied to feature extraction has higher per pixel pepper noise intensity. Hence, hybrid technique which comprises of GA and fuzzy inference system (FIS) has been used for urban feature extraction. The output is improved to a larger extent while applying GA along with FIS technique. Thus the number of buildings under influence and the impact on humans living in those buildings are analysed. Based on the building materials used the varying impact on humans is also studied. Hence the proposed method eliminates the problem of visiting the field which is very time consuming. The impact can be analysed by just using the satellite images of the region.

Fig. 1: Study area

Study Area and Data

Study Area: An intensive urban region (impervious surface) shown in Figure 1, which is very closer to Chennai is Chosen as study area. Its latitude and longitude are 12.95133 and 80.210205 respectively.

Remote - Sensor Data: Google Earth(GE) and Quick Bird imagery from Digital Globe, Inc., acquired on 10th may 2012 and 18th may 2005, were used to image analysis and segmentation.

Ground Reference Information: Random Sample tool in ArcGIS 9.3 is used to collect ground reference information to assess the accuracy of the building detections. Total of 40 point (polygon) sample were randomly generated for the study area. The urban building of each sample polygon was identified based on direct field visits with satellite image reference. Each reference point in satellite image and feature map has been verified with build up region map and ground truth information.

MATERIALS AND METHODS

Automatic feature extraction technique for building detection, along with ELF EMF influence assessment and spatial data analysis are integrated in the proposed methodology as shown in Figure 2. The methodology is implemented by the following three steps.

- Land Cover Map and Urban Building Detection
- Integration of Urban Building and EMF intensities; and
- Detection of Vulnerable Buildings by Spatial Analysis.

Land Cover Map and Urban Building Detection: In the proposed methodology, image segmentation is done to extract the building areas. Various image segmentation

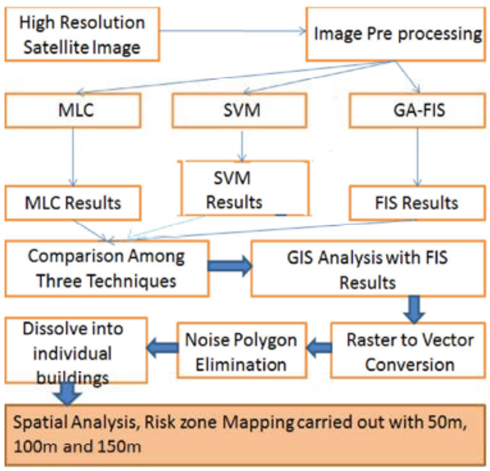

Fig. 2: Implementation of proposed work

techniques such as Maximum likelihood classifier, Support Vector Machine techniques and Genetic Fuzzy Hybrid method are used to extract the building areas. Image segmentation is the process of partitioning a digital image into multiple segments (into a set of pixels, which is also known as super pixels).The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics.

Image Segmentation Technique Has Two Types: Supervised method and Unsupervised method.

In supervised method, the image processing method is guided by the user to specify the land cover classes of interest. The user defines “training sites” – areas in the map that are known to be representative of a particular land cover type – for each land cover type of interest.

In unsupervised method, image processing method classifies an image based on natural groupings of the spectral properties of the pixels, without the user specifying how to classify any portion of the image.

Maximum Likelihood Classifier: Maximum-likelihood estimation (MLE) is a method of estimating the parameters of a statistical model. When applied to a data set and given a statistical model, maximum-likelihood estimation provides estimates for the model's parameters.

In general, for a fixed set of data and underlying statistical model, the method of maximum likelihood selects the set of values of the model parameters that maximizes the likelihood function. Intuitively, this maximizes the "agreement" of the selected model with the observed data and for discrete random variables it indeed maximizes the probability of the observed data under the resulting distribution. Maximum-likelihood estimation gives a unified approach to estimation, which is well-defined in the case of the normal distribution and many other problems. This method is of unsupervised type, where the training areas are given for extraction of buildings. In this case, three training areas are selected; the vegetation, the buildings of white colour and the buildings of grey colour from the data image.The output obtained through MLC is shown in Figure 3.

Urban Building Detection by Support Vector Machine (SVM) Technique: A support vector machine (SVM) is used when the data has exactly two classes. An SVM classifies data by finding the best hyperplane that separates all data points of one class from those of the other class. The best hyperplane for an SVM means the one with the largest margin between the two classes. Margin means the maximal width of the slab parallel to the hyperplane that has no interior data points.

The support vectors are the data points that are closest to the separating hyperplane; these points are on the boundary of the slab. The image obtained by Support vector machine shown in Figure 4 is better when compared to maximum likelihood classifier results. This resultant output is used to identify buildings coming under vulnerable areas[8-10].

Urban Building Detection by GA-FIS Based Hybrid Technique: Identification of individual building is very difficult form the coarse resolution satellite imagery. Hence high resolution satellite image has been used for urban building detection. GA is a global optimization technique which is used to find the solution to the problem with multi-objective function. As GA is an evolutionary algorithm, it provides better convergence to find solution. Further, in order to obtain Precise solution FIS technique is combined with GA by considering textural properties of the building along with their intensities. The output obtained through GA-FIS technique is shown in Figure 5.

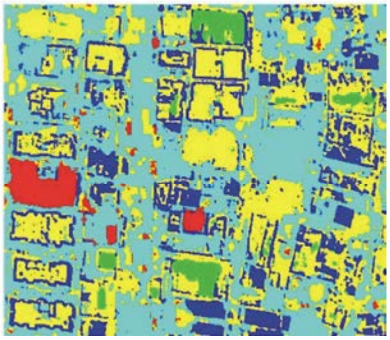

Fig. 3: MLC classified image

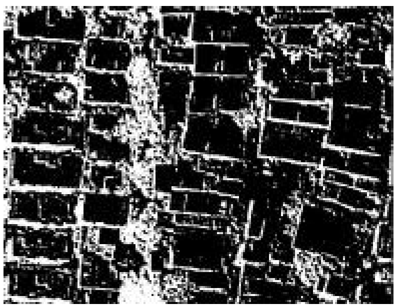

Fig. 4: SVM classified image

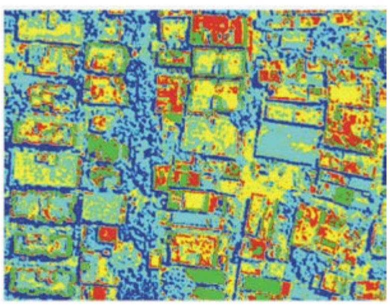

Fig. 5: GA-FIS based image classification

Integration of Urban Buildings and EMF Intensities: With the integration of the calculated EMF intensities and land cover feature, the EMF spread is obtained for the study area. Once EMF spread is detected and then Urban Building which falls under the critical zone is focused and proximity analysis is performed.

Detection of Vulnerable Buildings by Spatial Analysis: After the integration of Urban feature and EMF intensities, spatial analysis is performed by loading the urban features in ARCGIS software. The extracted features are geo referenced with the help of Ground Truth Map. At various space intervals the EMF spread with respect to the HT lines are calculated.EMF calculated at every one meter space interval is shown in Table 1. Proximity analysis is performed around the HT lines by buffering the region around the line at 50 meter space interval to detect the buildings which are under vulnerable zone.

Calculation for Electric Field and Magnetic Field Strength

Electric Field Strength: The electric field is split into the horizontal and vertical component for calculation and then combined together using equations (1-4).

$$E_{pxi} = \frac{1}{2\pi\varepsilon_0\varepsilon_r}\sum_{k=0}^{n} q_k x_{pk} F_{pki} \quad (1)$$

$$E_{pyi} = \frac{1}{2\pi\varepsilon_0\varepsilon_r}\sum_{k=0}^{n} q_k y_{pk} F_{pki} \quad (2)$$

$$F_{pki} = \left[\frac{1}{r_{pku}2} - \frac{1}{r_{pki}2}\right] \quad (3)$$

$$E = \sqrt{E_{pxi}2 + E_{pyi}2} \quad (4)$$

where,

E - Net electric field strength at the point P

Q - Charge density

X_{pk} - Horizontal distance between 'k'th phase and point P

Y_{pk} - Vertical distance between 'k'th phase and point P

ε_r - Relative permittivity of medium (relative permittivity of different material is shown in table 2)

r_{pk} - Distance between the phase k and the current point P

r'_{pk} - Distance between the phase k and the current point p.

The electric field strength E depends on the electrical charges from the three-phase conductor, the geometrical design of the pillar and the lines. Using the Maxwell equations for capacities, the linear distributed electrical charge on the phase conductors is:

[U]= [p] [Q] (5)

where,

[U] - The phases potential matrix (toward the earth)

[p] - Potential coefficients matrix

Table 1: Calculation of EMF

Distance (in metres)	Magnetic Field Strength (tesla)	Electricfield Strength(V/m)
1	5.45841E-06	10541.81
2	5.56525E-06	19536.12
3	5.76784E-06	20603.03
4	6.0425E-06	21108.69
5	5.15172E-06	21078.05
6	6.54127E-06	20590.82
7	6.65574E-06	19758.45
8	6.66104E-06	18698.14
9	6.57233E-06	17513.6
10	6.41078E-06	16285.84
11	6.19577E-06	15072.04
12	5.94303E-06	13908.82
13	5.66529E-06	12817.11

Table 2: Relative permittivity of different building materials

Building Materials	Relative Permittivity
Glass	3.8
Granite	8
Marble	8
Wood	1.4
Fiber Glass	6
Mica	5
Cement	6

Magnetic Field Strength: Magnetic fields are produced where electric current is present. The strength of a magnetic field at a given location depends on the level of current flowing in the conductor or wire and the distance from it. Magnetic fields are normally expressed in terms of a quantity called the magnetic flux density, expressed in terms of tesla (T). This relatively large unit is often expressed in submultiples such as micro tesla (μT - one millionth T). The magnetic field calculator is based on the Biot-Stavart law. The Magnetic field produced by each segment carrying an electrical phasor current I is given by equations.

$$B_{pxi} = \frac{\mu_0 \mu_r}{2\pi} \sum_{k=0} \frac{y_{pki}}{r_{pki} 2} I_k \quad (6)$$

$$B_{pyi} = \frac{\mu_0 \mu_r}{2\pi} \sum_{k=0} \frac{x_{pki}}{r_{pki} 2} I_k \quad (7)$$

$$B = \sqrt{B_{pxi} 2 + B_{pyi} 2} \quad (8)$$

where,

B_{px} is represented with real part value of current.

B_{py} is the imaginary part value of current.

r-Radius of the conductor in metre

Table 3: EMF by considering a building of height 10m made up of concrete with relative permittivity value 6 as obtained from data sheet

Distance (in metres)	Magnetic Field Strength (tesla)	Electric Field Strength (V/m)
1	4.63965E-06	1756.968
2	4.73046E-06	3256.02
3	4.90266E-06	3433.839
4	5.13613E-06	3518.116
5	4.37896E-06	3513.008
6	5.56008E-06	3431.803
7	5.65738E-06	3293.075
8	5.66189E-06	3116.357
9	5.58648E-06	2918.933
10	5.44916E-06	2714.307
11	5.26641E-06	2512.007
12	5.05158E-06	2318.136
13	4.8155E-06	2136.185

Table 4: EMF by considering a building of height 10m made up of glass with relative permittivity value 3.8 as obtained from data sheet.

Distance (in metres)	Magnetic Field Strength (tesla)	Electric Field Strength (V/m)
1	5.34924E-06	2774.159
2	5.45395E-06	5141.085
3	5.65248E-06	5421.85
4	5.92165E-06	5554.919
5	5.04868E-06	5546.855
6	6.41045E-06	5418.636
7	6.52263E-06	5199.593
8	6.52782E-06	4920.563
9	6.44088E-06	4608.842
10	6.28256E-06	4285.748
11	6.07186E-06	3966.327
12	5.82417E-06	3660.215
13	5.55199E-06	3372.924

The Electric and magnetic field is calculated considering a point at a height of 10 m for a 132 KV transmission line at various distances is given in Table 1.

Calculation of EMF for Various Building Materials: The U.S. National Institute of Standards and Technology (NIST) conducted extensive tests in 1997 on how various common building materials can shield (dampen) electromagnetic fields. A wide range of materials and thicknesses were tested, such as bricks, concrete, lumber, drywall, plywood, glass and rebar.

For shielding of humans against EMF, these are the magnitudes that are relevant. On this scale, only thick concrete and very thick lumber (logs) are of any practical interest. The shielding values do vary with the frequency, with the materials mostly performing better at higher frequencies. However, that is not always the case.

The efficiency of concrete structures as a shielding material depends on its electromagnetic properties: electrical conductivity, permittivity and magnetic permeability. As concrete is a nonmagnetic material, its magnetic permeability is deemed equal to that of free space. The Relative permittivity of different building materials is given in Table 2.

The electric and magnetic field for various building materials namely cement with relative permittivity equal to 6 and glass with relative permittivity equal to 3.8 are shown in Table 3 and 4 respectively.

RESULTS AND DISCUSSION

In the proposed work the image classification and feature extraction are performed using MLC, SVM and GA-FIS technique. Three levels of image classification have been performed for feature extraction. The build up region are depicted on the study area in the first level. Urban buildings are depicted for the given study area and the building roof nature are distinguished with different specifications in second and third level respectively.

The Google Earth (GE) image of the study area is shown in Figure 1. The output of MLC based feature extraction is shown in Figure 3. The output of SVM and GA based feature extraction is shown in Figure 4 and 5 respectively. The variation of Electric and magnetic field at various distances and are shown in Table 1, 3 and 4 respectively. With the help of ARCGIS, extracted urban buildings and computed EMF values are integrated. The complete implementation of proposed work is shown in Figure 2. The false positive urban building polygons are eliminated using grid code query analysis and the identified vulnerable zones and buildings with the help of spatial analysis is depicted in Figure 6. In this proposed work, the urban feature extraction is effectively applied for Vulnerability analysis of HT lines. GIS based spatial analysis is carried out by considering EMF intensities along with building nature. Vulnerable zones are buffered using Arc-GIS and specific building roof structures are identified to evaluate the EMF influence on individual or group of buildings. From the results it is very clear that rapid urbanisation near HT power lines will impose health and psychological disorders on residential community. Thus without actually visiting the field, the proximity analysis has been carried out using satellite image and remote sensing technique for identifying the urban features which are under vulnerable zones.

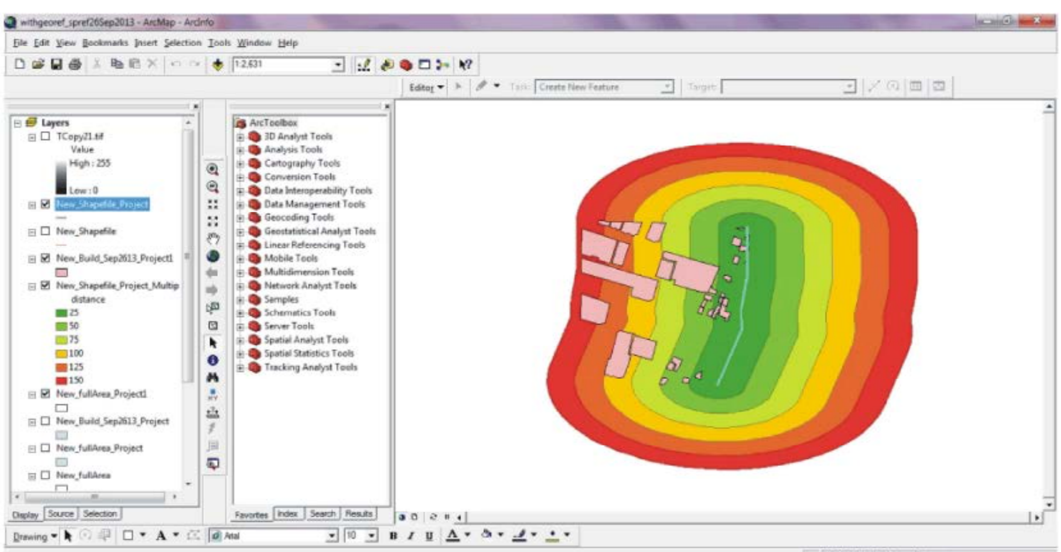

Fig. 6: Buffered Output with 50,100 and 150 meters

CONCLUSION

The impact of High tension transmission lines on living areas have been analysed and tabulated. The theoretical calculation of electric and magnetic fields have been performed and the values are cross referenced with the basic limit set by International exposure levels of EMF. Building extraction is performed with the help of Image classification techniques. Three types of classifications have been used to compare and the most optimised result has been obtained. Using this data the number of buildings under influence and the impact on humans living in those buildings is analysed. Based on the building materials used, the varying impact on humans is also studied. Hence it can be concluded that this analysis eliminates the problem of visiting the field which is very time consuming and the impact can be analysed by just using the satellite images of the region.

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