

(ISSN: 0794-9154)  
Volume 8, Number 1, 2017

# Nigerian Journal of Tropical Geography

Promoting International Geographical and Environmental  
Research for Sustainable Development and Solutions



Published by:  
Department of Geography  
Nasarawa State University  
P.M.B. 1022, Keffi, Nigeria



# **Nigerian Journal of Tropical Geography**

*Volume 8, Number 1, 2017*

## **CONTENTS**

### **Editorial**

Nasiru Medugu Idris

- AN ANALYSIS OF AGRO-WASTE SOURCES AND ITS BIOGAS POTENTIALS IN LAGOS** 1321

Adedayo Vide, Fashua Kehinde, Edeh, Nnenna and Adeyemi, Olusegun

- INTRA-REGIONAL DISPARITY IN NORTH WESTERN STATES OF NIGERIA: EVIDENCE FROM EDUCATIONAL ENROLMENTS** 1336

Abdullahi Abubakar, Peter Elias, & Olatunji Babatola

- MAPPING ENVIRONMENTAL PROBLEMS IN NIGERIA** 1361

Mayowa Fasona, Olatunde Ogunkunle, Vide Adedayo and Ajibade Ariori

- MINERAL POTENTIAL MAPPING USING GIS: A CASE STUDY OF LIMESTONE DEPOSIT OF EASTERN DAHOMEY BASIN, SOUTH-WESTERN NIGERIA** 1376

Nkiru Rita Orefo, Peter Elias & Akinlabi Akintuyi

- SOLID WASTE MANAGEMENT PRACTICES IN LAGOS STATE: CASE OF KOSOFE LOCAL GOVERNMENT AREA, LAGOS STATE** 1394

Ayeni, A. O. and Ogunkunle, O. J.

- SPATIAL DISTRIBUTION OF CRIME: INSIGHTS FROM AKOKA CAMPUS OF THE UNIVERSITY OF LAGOS** 1415

*Franca Attoh, PhD*

- INDICES BASED ANALYSIS OF DROUGHT AND ARIDITY IN PARTS OF NIGERIA'S SAVANNAH** 1441

*O. Adegun & A.O. Ayeni*

- THE USE OF GEOSPATIAL APPROACH IN IDENTIFYING URBAN HEAT ISLAND ANALYSIS FOR SUSTAINABLE ENVIRONMENTAL MANAGEMENT IN AKURE, NIGERIA.** 1454

*Liman, H.M<sup>1</sup>, Davids A. A<sup>2</sup>, and Dangana K.<sup>1</sup>*

- EVOLUTION OF LATRITIC DURICRUSTS AROUND NIGERIAN DEFENCE ACADEMY AFAKA, KADUNA NIGERIA** 1465

*Ali Williams BUTU and Aliyu DADAN-GARBA*

- RAINFALL VARIABILITY OVER GUSAU AND ENVIRONS, ZAMFARA STATE, NIGERIA** 1477

*Ibrahim Ishiaku, Ismail Usman Kaoje<sup>1</sup>, Emigilati M.A, Suleiman Y. M.<sup>2</sup>,*

|                                                                                                                            |      |
|----------------------------------------------------------------------------------------------------------------------------|------|
| <b>PROSPECTS AND CHALLENGES OF WATER RESOURCES<br/>AND ENVIRONMENTAL MANAGEMENT IN NIGERIA:<br/>AN OVERVIEW</b>            | 1486 |
| <i>Suleiman, Y.M.; Emigilati, M.A.; Abdulkadir, A.<sup>1</sup>; Liman, H.M.<sup>2</sup> and Umar, B.<sup>3</sup></i>       |      |
| <b>AN OVERVIEW OF QUALITATIVE RESEARCH<br/>PARADIGM IN ENVIRONMENTAL DESIGN DISCIPLINES</b>                                | 1507 |
| <i>Mohammed, Moukhtar Mai</i>                                                                                              |      |
| <b>A COMPARISON OF DATA FROM DGPS AND GPSS<br/>OBSERVATIONS</b>                                                            | 1530 |
| <i><sup>1</sup>Babalola A. and <sup>2</sup>Emmanuel B.</i>                                                                 |      |
| <b>THEORY AND RESEARCH: AN INTER-FUNCTIONAL NEXUS</b>                                                                      | 1539 |
| <i>Ochapa Adadu.</i>                                                                                                       |      |
| <b>ASSESSMENT OF HOUSEHOLD WATER DEMAND AND CONSUMPTION<br/>IN YOLA NORTH L.G.A. ADAMAWA STATE, NIGERIA</b>                | 1550 |
| <i>*Abubakar Bashir, Hamza, A. and Kefas, J.</i>                                                                           |      |
| <b>APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEM<br/>AND THE THEORY OF EVIDENCE FOR WASTE DISPOSAL<br/>SITE SELECTION.</b> | 1564 |
| <i>Ayo Babalola</i>                                                                                                        |      |

# APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEM AND THE THEORY OF EVIDENCE FOR WASTE DISPOSAL SITE SELECTION.

Ayo Babalola

[babalola.ayo@unilorin.edu.ng](mailto:babalola.ayo@unilorin.edu.ng) or [babaayo547@gmail.com](mailto:babaayo547@gmail.com)

Department of Surveying and Geo-informatics,

Faculty of Environmental Sciences, University of Ilorin, Ilorin, Nigeria

Tel: 07063988323 or 08179290547

**ABSTRACT:** *The increase in population and improved life style have led to the growth in the amount of municipal solid waste generation the world over, and the need to identify or locate suitable place (s) for these wastes to be dumped has also increased tremendously. This paper provides an overview of the theory of evidence and its applications to solid waste management. The theory of evidence particularly, Bayesian probability and the Dempster-Shafer theory (DST) approaches has emerged and has found favour in many types of applications such as signal detection, image classification, and sensor fusion. Here the DST approach is used to identify suitable sites for landfill in Damaturu. The DST method shows promise for the identification or location of sites for Waste management.*

**Keywords:** *Theory of Evidence, Dempster-Shafer, GIS, Landfill, Waste Management*

## 1.0 Introduction

Site selection particularly solid waste disposal site has received wide attention due to the impact it has on the economy, social and environmental health concerns. Increasingly, the growth in population and improved living standards are contributing to the rise in the generation of wastes in urban areas. Again, rapid urbanization of towns and cities is also a major cause of the increase in the volume of wastes. Management of

solid waste lies within the purview of the environmental protection agency (EPA) of the state. In most towns in Nigeria, the rate of waste generated has increased tremendously due to the rise in population while the waste disposal and management remains ineffective. As part of such ineffective management process the final disposal sites for waste do not consider environmental factors. Locally, site selection for solid waste disposal is done by dumping in

any vacant plot, rivers, and ponds in and around the town. Mainly due to the fact that the disposal sites are located without considering features such as roads, residential areas, river, and institutions. In order to locate a suitable waste disposal site, many siting criteria and factors must be considered. For instance Lofti, et al. (2009) considered land potential, distance to fault line, wind direction, topography, and distance from legal limit of the city, land limitations, distance from major roads, distance from rivers and distance from urban infrastructure in order to determine the best land for urban expansion. In a study carried out by Rahman and Hoque, (2007) they applied the geographic system approach to conduct a site suitability analysis for the purpose of solid waste disposal. In their work, they used what they called local factors and criteria classified as environmental, economic, social and technical-operational. Cheng, et al. (2003) used an approach they called an integrated multi-criteria decision analysis and inexact mixed integer programming for solid waste management. They concluded that several multi criteria decision analysis techniques should be applied to deal with site selection problem.

Vuk et al. (1991) showed the efficacy of applying the MCDA methodology for solid waste management. Sumathi, et al. (2007) demonstrated the effectiveness of using a geographic system approach for optimized siting of municipal solid waste landfill. In their work, they considered land use criteria, hydro-geologic criteria, and air quality criteria. They concluded that the approach is flexible as it can be applied to different sites with diverse local conditions. In this paper, we present our work in locating a new landfill site in the city of Damaturu where there will be least environmental and economic impacts. Geographic information systems and Dempster-Shafer theory are capable of handling this problem. In the rest of the paper, section 2 gives a background on the study area. In section 3, the proposed GIS and Dempster-Shafer theory approach are described. Section 4, presents the results and discussions, and lastly, section 5 is a brief conclusion on the study.

## 2. Study area

Damaturu is one of the states capital in Nigeria, it lies between longitude  $11^{\circ} 44' 40''$  and latitude  $11^{\circ} 57' 40''$  and having a total land area of about  $400\text{km}^2$ , situated in the north eastern part of Nigeria.

The main urban area constituting the city occupies an area of about 20 km<sup>2</sup>. The state shares boundaries with Bauchi, Borno, Gombe and Jigawa states, and borders the nation of Niger Republic. The topography is flat with local relief usually less than 120 meters, and wind direction from north to north-east at an average speed of 4.89 m/s. Damaturu the Yobe state capital rose from an obscure local government area to the status of a state capital in 1991. The sudden change in status brought about the increase in population from less than 10,000 inhabitants before 1991 to a Population of about 255,895 (GeoNames 2010).

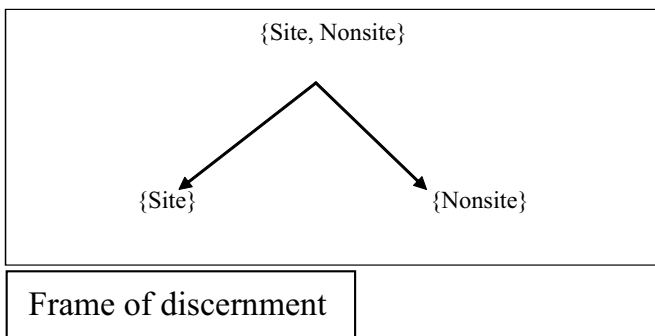
### 3. Methodology

#### 3.1 Dempster-Shafer theory of evidence (DST)

The Dempster-Shafer theory of evidence was first introduced by Dempster in 1967 and further developed by Shafer in 1976 hence the name Dempster-Shafer. DST is a popular method in the

field of artificial intelligence. It is sometimes referred to as an extension of the Bayesian theory; it provides belief functions which differentiate between uncertainty and ignorance. DST is a potent approach for handling ignorance, incomplete information or the lack of it.

In the analysis, the decision frames or frame of discernment (Figure 1) are whether geographical units are suitable or not suitable for the siting of landfill in the study area based on specific criteria. Criteria here mean factors that affect the suitability of a particular place or location. In this work a method of indirect evidence for inference making is considered called DST. Inference using the DST approach involves statements about belief in, and plausibility of, a given pixel being suitable for siting landfill given the evidence presented. Below is the process of constructing the frame of discernment.



## **Figure 1: Frame of Discernment (Decision Frame)**

The frame of discernment bears the entire hypothesis including all possible combinations. The entire pieces of evidence are made to either support site or nonsite. This is thereafter added and combined to produce the basic probability assignments (Shafer, 1976)

## **4. Results and Discussions**

### **4.1 Implementation Process**

This section presents and discusses the data conversion procedure as well as the results obtained from the analysis. The application of DST requires a software package like the IDRISI (Eastman, 1997). This is a geographic information and image processing software system developed by the graduate school of geography at Clark University. In this software the belief module implements the Dempster-Shafer logic.

Firstly, the belief constructs and stores the current state of knowledge for the hierarchy of hypotheses formed from a frame of discernment. Then the basic elements are entered, all the hypotheses in the hierarchical structure will then be in the hypothesis list. Secondly, for each line of evidence that is entered, the basic probability

assignment will then be needed. Thirdly, from the ANALYSIS menu, the BUILT KNOWLEDGE BASE item then incorporates the new evidence by calculating the state of knowledge using the D-S rule of combination and thereafter, plausibility or belief interval statements for each hypothesis is selected. All the information entered is then saved in a knowledge base file for later use as soon as more evidence is obtained.

### **4.2 Data Conversion**

Before the commencement of the aggregation steps, all the evidences necessary are converted to stand for the strength of belief for instance, the aspect data is classified in such a way that areas that have aspects ranging between  $112^{\circ}$  and  $248^{\circ}$  are in favour with a value of 1, other areas with 0.44 and areas that are flat 0.19. Supporting evidence that represents the strength of belief for presence of site is the classification of areas near agricultural lands. Sites are simply classified so that areas closed to agricultural (Cultivated) areas with value close to 1 support sites and others are not.

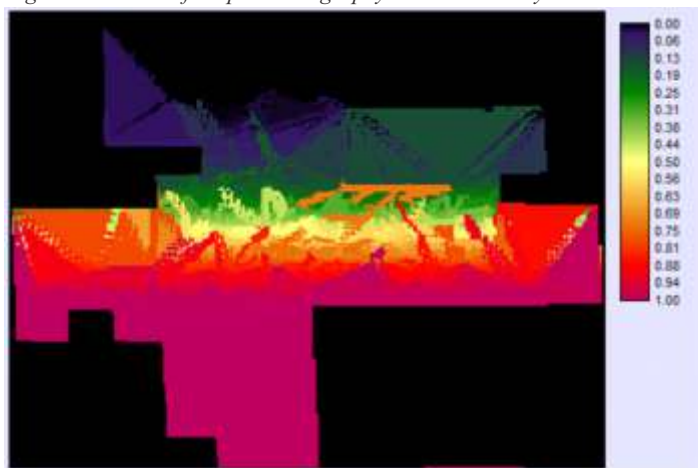


**Figure 2:** Aspect (site)



**Figure 3:** Cultivated Land (Site)

Next is the construction of data that are in support of the hypothesis {nonsite} beginning with the distance to existing roads, for as distance increases to the roads the probability for {nonsite} decreases. In this scenario a method of linear fuzzy was utilized. The probability ranges between 0-0.25 in support of the

hypothesis {nonsite}. This function is sigmodal and the fuzzy membership is reduced from 1 to 0.25. While the remaining evidence [1-road\_nonsite] produces the probabilities that support the hypothesis [Site, Nonsite]. This is referred to as ignorance (Babalola, 2011).



Figure 4: Road Nonsite

4.3Aggregation Process

Table 1: Computing BPA [Site]

| Orthogonal sum                                        | Agric                                     | $\Theta = 1 - \text{Agric}$          |
|-------------------------------------------------------|-------------------------------------------|--------------------------------------|
| Aspect                                                | $[\text{Site}] \bullet [\text{Site}] = A$ | $[\text{Site}] \bullet [\Theta] = B$ |
| $\Theta = 1 - \text{Aspect}$                          | $[\text{Site}] \bullet [\Theta] = C$      | $[\Theta] \bullet [\Theta] = D$      |
| $\text{BPA} [\text{Site}] = m([\text{Site}]) = A+B+C$ |                                           |                                      |

From here other evidences are added to produce the final BELIEF [Site]. The calculation is not an ordinary summation but orthogonal in consonance with the D-S rule which stipulates that the addition of all BPAs must be equal to 1. In this case, the formula adds up all available information. Table 2 is an example of aggregation of fact in favour of[Nonsite].

Table 2: Computing BPA [Nonsite]

| Orthogonal sum                                              | Road                                            | $\Theta = 1 - \text{Road}$              |
|-------------------------------------------------------------|-------------------------------------------------|-----------------------------------------|
| Road                                                        | $[\text{Nonsite}] \bullet [\text{Nonsite}] = A$ | $[\text{Nonsite}] \bullet [\Theta] = B$ |
| $\Theta = 1 - \text{Road}$                                  | $[\text{Nonsite}] \bullet [\Theta] = C$         | $[\Theta] \bullet [\Theta] = D$         |
| $\text{BPA} [\text{Nonsite}] = m([\text{Nonsite}]) = A+B+C$ |                                                 |                                         |

Finally, all the evidences are combined to determine the final BELIEF [Site]. The process of normalization of the evidences is carried out in order to handle evidences that might be conflicting (Table 3)

**Table 3:** Computing final BELIEF [Site]

| Orthogonal sum                                                     | m [Site]               | $\Theta = 1 - m$ [Site] |
|--------------------------------------------------------------------|------------------------|-------------------------|
| m [Nonsite]                                                        | [Site] • [Nonsite] = A | [Nonsite] • [Θ] = B     |
| $\Theta = 1 - m$ [Nonsite]                                         | [Site] • [Θ] = C       | [Θ] • [Θ] = D           |
| <b>BELIEF [Site] = [Site]/(1 - ([Site] • Nonsite)) = C/(1 - A)</b> |                        |                         |

The result shows the BELIEF [Site] which stands for all the evidences in the hypothesis [Site] Appendix A.

The DST model produces three outputs: belief, plausibility and the belief interval. The evidence supported the belief that the areas away from the centre of the town and within cultivated areas are suitable for the sitting of landfill. Again, the models suggested that it is plausible that many other areas of the study area are suitable for the siting of landfill, but there are no substantial statement about the belief that these areas are suitable could be drawn. The areas with highest belief interval are those with the highest level of uncertainty in terms of whether or not they are suitable for landfill, included areas that are further away from agricultural areas and closer to the city centre. These areas included near the state

television station in the northern part of the town, areas near industrial zone in the western part of the city, areas close to the state university along Biu road, and agricultural areas of Maiduguri road.

In the analysis, the research considered the hierarchical combination of the possible hypotheses which comprises [site], [nonsite], and [site, nonsite] with a binary result. The research is most concerned with the result got for the hypothesis [site]. Indirect evidence that is related to the possibility that a landfill will be sited is gathered. The probability images are created from the evidences provided. Next is aggregating the different line of evidence using the Belief module in IDRISI, example in the current state of knowledge box.

**Table 4:** Aggregating Evidence

| Caption     | Image Name         | Support Hypothesis |
|-------------|--------------------|--------------------|
| Water-body  | Water body NONSITE | [nonsite]          |
| Road        | ROAD_NONSITE       | [nonsite]          |
| Known sites | SITE_SITE          | [Site]             |
| Cultivation | AGRIC_SITE         | [Site]             |

From the Belief module the knowledge base is created using Analysis. All the evidence are combined and the basic probability assignments (BPAs) for all the hypotheses. From the extract summary, the result of the belief, plausibility, and belief interval files for the SITE hypothesis are respectively named BELIEF\_SITE, PLAUS\_SITE and INTER\_SITE. Thereafter, the relationship between the results and the evidence layers are explored considering the group file known as EVIDENCE which bear the files. The evidence supported the belief that areas outside the city centre that is near the city boundary are more suitable for siting landfill. In addition, the models indicated that many areas close to agricultural land are suitable for the siting of landfill. The frame of discernment bears two elements known as site and

nonsite.

In Dempster-Shafer theory, the basic probability assignment can relate to belief in Site, which powerfully support site and plausibility of site, which stands for the level to which site cannot be disbelieved. The difference between the plausibility and belief estimates is referred to as belief interval which stands for uncertainty in the acceptance or rejection of site. Belief appears to be higher around the points where there is supporting evidence. The belief interval for site shows the probability of potentials, that is the higher the probability, the more valuable further information will be in a location. Areas near the agricultural areas where the likelihood is highest of siting landfill. From the result obtained, it is quite clear that ignorance was highest where there is no sample information. Conclusively, the

Dempster-Shafer theory or the belief modelling is not a widely used technique especially among those concerned with analysing spatial data. Most of the studies done using the Dempster-Shafer theory approach are found in artificial intelligence.

## 5. Conclusion

The study observed that one of the major problems confronting the city's solid waste management practice is the lack of solid waste facility in place for proper waste disposal. Consequently, the study presented the results obtained from identifying sites that are suitable for landfill. Thereafter, DST which is very useful in dealing with uncertainty in judgments applied in the landfill siting process taking into cognisance the presence of uncertainty and ignorance in spatial data. The implementation and data conversion processes are discussed. In all the DST shows capability in handling landfill site selection modelling. Other evidence theory approach may be applied to compare the outcome.

## References

Babalola, A. (2011). Waste disposal site selection with the aid of geographic information system

modeling. *Unpublished Ph.D. Thesis*, Universiti Teknologi Malaysia.

Cheng, S., Chang, C.W., & Huang, G. H. (2003). An integrated multi-criteria decision analysis and inexact mixed integer linear programming approach for solid waste management. *Journal of Engineering application of artificial intelligence*. Vol. 16, 543-554

Dempster, A. P. (1967). Upper and lower probabilities induced by a multivalued mapping, *Annals of Mathematical Statistics*, Vol.38, 325-339.

Eastman, J.R. (1997). Idrisi for Windows, Version 2.0 Tutorial Exercises, Graduate School of Geography - Clark University, Worcester, M.A.

GeoNames. (2010). Geographical Database . <http://www.geonames.org/search.html> last accessed 2010-05-06.

<http://www.geonames.org/search.html> last accessed 2010-05-06.

Lofti, S., Kiomarth, H., & Mohammed, J. (2009). An analysis of urban land development using multi-criteria decision model and GIS (A case study of Babolsar city). *American Journal of Environment Sciences* Vol.5, 87-93.

Rahman, M., & Hoque, A. (2007). Site suitability analysis for solid waste disposal using GIS:

A case study on KCC Area. *Journal of Geo-Environment* Vol. 6, 72-86

Shafer, G. (1976). *A Mathematical theory of evidence*, Princeton University Press, Princeton and London.

Sumathi, V.R., Usha, N., & Sarkar, C. (2007). GIS-based approach for optimized siting of municipal solid waste landfill. *Journal of waste management*. Doi:10.1016/j.wasman.2007.09.032

Vuk, D., Kozelj, B., & Mladineo, N. (1991). Application of multicriteria analysis on the selection of the location for disposal of communal waste.

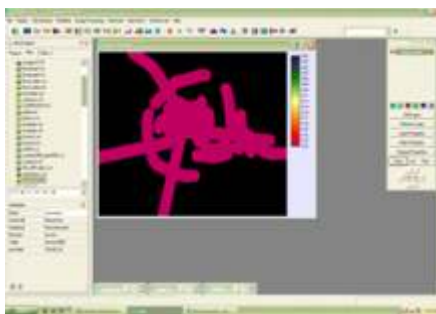
## Appendices

### A) Running fuzzy module

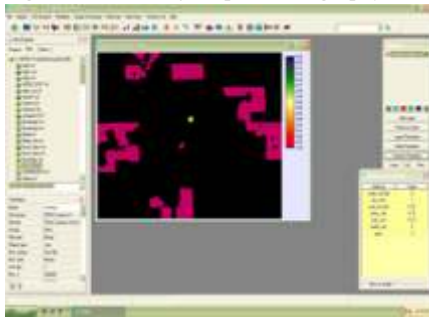


In this image ROAD\_NONSITE, the probability range 0-0.25 in favour of the hypothesis [nonsite]. It is still a sigmoidal function, but the maximum fuzzy membership is reduced from 1 to 0.25. The remaining evidence (1-ROAD\_NONSITE) produces the probabilities that support the hypothesis [site, nonsite]. This is known as ignorance, and it is calculated automatically by the Belief module.

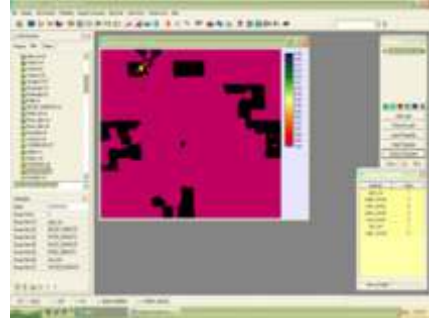
### B) Running the SCALAR module



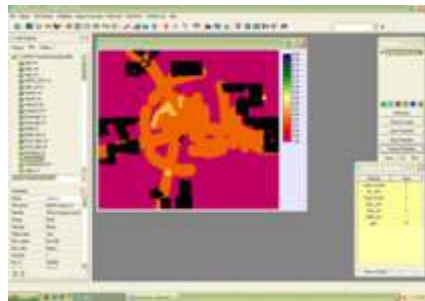
### C) i) Evidence.Belief\_Site



ii) Evidence.Inter\_Site



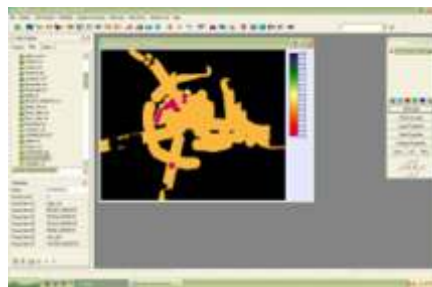
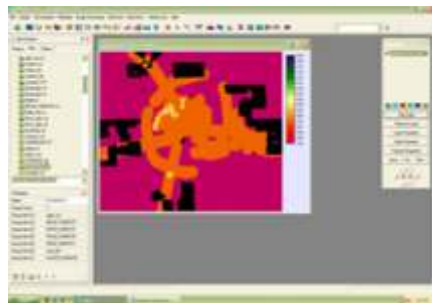
iii) INTER\_NONSITE



iii) Evidence. Plausibility\_Site

D) EVIDENCE 2

i) BELIEF\_NONSITE



ii) PLAUS\_NONSITE