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Application of Raster Images in Computing Environmental Risk Assessment (ERA) of Pipelines

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Abstract: The raster data model sub-divides space into square pixels or other regular tessellations to provide a continuous representation of the study area rather than subdividing it into discrete points, lines, or polygons. This study presents the application of raster images in assessing the environmental risks of pipelines. Based on the results of the investigations, one of the main conclusions drawn was the inevitable and rational practicality of raster images in order to assess the environmental risks of pipelines more accurately and precisely than that of using vector-based GIS. Another important conclusion indicated that raster images should not be used for data storage in environmental risk assessment of pipelines due to the plenty of required data layers used. A cell size of 20m is rational for the environmental risk assessment of pipelines crossing the ecosystems not varying vastly like the case study. In those cases vastly varying due to topography and other involving factors, the cell size may be as small as 5m.

Key words: ERA · Pipeline · GIS · Raster Image · Assalouyeh

INTRODUCTION

Risk is the intensity of the consequences of a hazardous material or an activity considering their probability of occurrence. Pipeline failures cause severe damages. Environmental risk assessment (ERA) involves the examination of risks resulting from natural events (flooding, extreme weather events, etc.), technology, practices, processes, products, agents (chemical, biological, radiological, etc.) and industrial activities that may pose threats to ecosystems, animals and people. Environmental health risk assessment addresses human health concerns and ecological risk assessment addresses environmental media and organisms. ERA is predominantly a scientific activity and involves a critical review of available data for the purpose of identifying and possibly quantifying the risks associated with a potential threat [1].

A paper described how HSE has piloted a Geographic Information System (GIS) by [2]. To support the expert decision making process and to assist in ensuring consistent responses within statutory deadlines. It considers both the advantages and disadvantages of a GIS over more conventional methods as well as potential developments such as the use of population data in considering societal risks, biological constraints and 3D terrain mapping. A very important index in ERA of pipelines is Environmental Sensitivity Indices (ESI) [3]. ESI composed of many field-data are essential for monitoring and control systems [4]. Reference [5] carried out a sensitivity analysis of the Korean composite environmental index (CEI) by examining the CEIs computed by functional forms and those derived from opinion surveys, with a special emphasis on the assessment of weights of environmental indicators and themes: the CEIs are based on environmental themes and pressure indicators. NOAA's (National Oceanic and Atmospheric Administration) Environmental Sensitivity Index (ESI) approach systematically compiles information in standard formats for coastal shoreline sensitivity, biological resources and human-use resources. ESI maps are useful for identifying sensitive resources before a spill occurs so that protection priorities can be established and cleanup strategies designed in advance. Using ESIs in spill response reduces environmental consequences of the spill and cleanup efforts [6]. Environmental Sensitivity

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Index (ESI) maps have been an integral component of oil-spill contingency planning and response since 1979, when the first ESI maps were prepared days in advance of the arrival of the oil slicks from the IXTOC 1 well blowout in the Gulf of Mexico. Since that time, ESI atlases have been prepared for most of the U.S. shoreline, including Alaska and the Great Lakes. Before 1989, traditional sensitivity maps were produced as color paper maps, with limited distribution (because of the cost of reproduction) and without a means for ready updating. However, since 1989, ESI atlases have been generated from digital databases using Geographic Information System (GIS) techniques. As the oil-spill response community moves towards development of automated sensitivity maps, it is important to define what comprises the ESI mapping system and how this information is being developed and distributed using GIS technology [7].

Raster is a method for the storage, processing and display of spatial data. Each area is divided into rows and columns, which form a regular grid structure. Each cell must be rectangular in shape, but not necessarily square. Each cell within this matrix contains location co-ordinates as well as an attribute value. The spatial location of each cell is implicitly contained within the ordering of the matrix, unlike a vector structure which stores topology explicitly. Areas containing the same attribute value are recognized as such, however, raster structures cannot identify the boundaries of such areas as polygons [8]. We have seen that relational database management systems and vector GIS are closely related vector GIS is basically built from the principles of relational databases, extending their storage, associative and query capabilities into two dimensions. Raster GIS is very much different from relational and vector GIS systems in each of these capacities. Relational tools are useful when dealing with rasters and their value tables, but the basic representations associations and transformations that we do with rasters are fundamentally different. Raster GIS provides us with new structures for representing conditions and events and they lend themselves to a vastly different vocabulary of operations for transforming and associating these references space [9]. Raster structures may lead to increased storage in certain situations, since they store each cell in the matrix regardless of whether it is a feature or simply 'empty' space [8].

The raster data model sub-divides space into square pixels or other regular tessellations to provide a continuous representation of the study area rather than subdividing it into discrete points, lines, or polygons.

Table 1: Comparison of raster and vector file formats [8]

Characteristics	raster	vector
Precision in graphics		√
Traditional cartography		√
Data volume		√
Topology		√
Computation	√	
Update	√	
Continuous space	√	
Integration	√	
Discontinuous		√

For example, to represent relief each pixel might have its height as an attribute; to represent land use each pixel would have a land use class attached to it and so on. Although less likely to be of use to historians, satellite images are a more complex form of raster data. On the image the earth's surface is sub-divided into pixels with each pixel storing information about the amount and type of light being reflected by that part of the earth's surface, for example, how much green, how much blue, how much red and how much infra-red [10].

The distinction between what is controlled and what is measured is important for geographic representation. If the attribute is fixed and the space is measured, the resulting representation is a vector representation showing the extent of the attribute; if the space is fixed and the attribute is measured, the resulting representation is a raster representation. Of course, there are exceptions and limitations to this approach, which is why we say it is the way that geographic information is usually collected [11]. A comparison of raster and vector file formats is presented in Table 1.

A pixel is the contraction of the words picture element commonly used in remote sensing to describe each unit in an image. In raster GIS the pixel equivalent is usually referred to as a cell element or grid cell. Pixel/cell refers to the smallest unit of information available in an image or raster map. This is the smallest element of a display device that can be independently assigned attributes such as color [8]. The raster data structure is a particular case of a tessellation [12]. Raster data can be shown either as cells, which take up an area, or as a pixel, which is single dot, much like the dots making up the image on a TV screen, which combined show an area. Remote sensing distinguishes between spatial, temporal and spectral resolution. Spatial resolution is the size of the unit recognized by the sensor, temporal resolution has to do with how often a satellite passes over and/or takes readings of the same spot and spectral resolution measures the range of wavelengths the sensor can record.

A raster cell is often also referred to as a "pixel" [11]. The raster data structure is characterized by a grid of cells, usually square, known as pixels. Since only a value of each phenomenon is associated to each cell, in the raster data structure, the geographical space is considered discrete. This type of structure adapts well to the representation of surfaces, even though its resolution is conditioned to the dimension of the cells. The raster data structure may also be used to represent objects. Each object is represented explicitly by a set of contiguous cells, corresponding to the same attribute value, such as soil type or slope classes.

The raster data structure may also be used to represent objects. Each object is represented explicitly by a set of contiguous cells, corresponding to the same attribute value, such as soil type or slope classes [12]. In contrast to surface analysis, which uses vector data, grid analysis is based on raster data. The regular arrangement of geographic units in raster data does not render any spatial interpolation necessary. Grids are common data formats for many data sources of spatial information, such as satellite imagery or scanned aerial photographs or maps. The identical size and shape as well as the spacing of geographic units make multilayer operations easy and efficient and allow for organizing different features in the same layer. However, grid formats have some disadvantages. Redundancy occurs where grid cells are smaller than the spatial variation. Grid cells which are too large to resolve spatial detail problems result in difficulties in assigning grid values [13]. With biodiversity data, a raster format can be particularly effective for displaying results and especially for biodiversity units that cover substantial areas, such as large vegetation units, or modeling predicted distributions of species. A raster format is not recommended for storing input data, unless the pixels are extremely small, i.e. equivalent to points, or otherwise very much smaller than the scale at which analyses will be required. This is because of difficulties in disaggregating data for areas that are subsets of individual pixels or that cross pixel boundaries. In such cases it is uncertain whether or not the pixel attributes apply to the areas under investigation and the data may therefore be unusable [14]. Underestimation will depend on the size of the small patches relative to the area of the single big patch, raster cell size and the grid for patch spraying [15]. Raster data are stored in an array of rows and columns of cells with each cell holding a single value characterizing all of the area within that cell. Image datacollected by satellites are a special type of raster data [16]. These data layers have a grid structure composed of equally sized square cells. Each cell represents a discretely uniform unit of area. This type of data layer was used for two primary reasons. First, many GIS software packages have tools for incorporating raster layers into mathematical operations. Second, raster layers that have been created with consistent settings ensure the same spatial coordinates for each cell each year, allowing temporal changes to be evaluated [15]. The raster structure is based on picture units (pixels); a map is decomposed into pixels and each pixel is referenced by its row and column position. Each pixel has a given size and attributes are assigned on a per pixel basis. For a given area for each attribute to be assigned (e.g., ownership, land cover, road networks) an individual raster (data layer) can be constructed. Raster data structures offer a few of advantages [13]:

- They are simple and easy to reference.
- They represent continuous surfaces.
- Combination of different data layers is easy.
- A large amount of spatial information is available in raster format, for example, remote-sensing data, or scanned maps and data bases can easily be constructed by importing raster data.

However, there are several disadvantages associated with raster data structures [13]:

- In many cases raster data are subject to data redundancy. As a uniform pixel size has to be chosen for each attribute it is likely that a large area is represented by a huge number of pixels all containing the same information.
- The aesthetic appearance of a map depends on the raster size. Linear features are either lost or overrepresented in crude raster formats.
- Topological relationships are hard to capture.
- Spatial data coded in raster format are distorted by transformations. For example, a line feature rotated by a specific angle and then rotated back may be different from its original shape.
- The accuracy in spatial analyses tends to be lower than desired. For instance, the length of a line can be computed exactly if the starting and end points are given, but can only be approximated when the line is represented in raster format

Although raster-based systems which could be regarded as 3D GISs are available, they may not be able to maintain the knowledge about reality available in the original data set. This knowledge may be lost because of problems in resolution and resampling [17].

Raster data structure is an abstraction of the real world where spatial data are expressed as a matrix of cells or pixels, with spatial position implicit in the ordering of the pixels. With the raster data model, spatial data are not continuous but divided into discrete units. This makes raster data particularly suitable for certain types of spatial operation, for example overlays, area calculations, or simulation modeling, where the various attributes for each pixel can be readily manipulated because they are referenced to a common geographic base. Unlike vector data however, there are no implicit topological relationships. Remote sensing data are largely stored and manipulated in raster form [14].

MATERIALS AND METHODS

Indicating the significance of the mentioned application, the raster images that have been created using an especial methodology in ERA of a pipeline as a case study, were discussed only for the purpose of case stating and not to represent the results of pipeline risk assessment-that was not the aim of this study.

Study Area: Being located beside the Kangan city the capital of Assalouyeh main city (Figure 1), the Assalouyeh-Bandarabbas gas pipeline project is to be routed through the mentioned city and be continued along about 385km. The pipeline is to carrying natural gas with 36 inches of diameter. The case study is the first 29.872km of the project. The study area selected is located along a national park called Naayband, introduced subsequently. It is worthwhile mentioning that all geographical coordinates for locations are available in the created maps. Topography is loosely constant all over the study area so that it did not affect the method used for the study area. The study area is partly in coastal zone.

The Most High-Value Area, Naayband National Park: Having a great value of biological, ecological, aesthetic and recreational aspects as well as intact flora and fauna to some extent, Naayband with an area of 476.871km^2 is a marine national park, comprising of a great number of fragile ecosystems. It is located in 300km southeast Boushehr Port including a part of Persian Gulf. The pipeline is routing along this park.

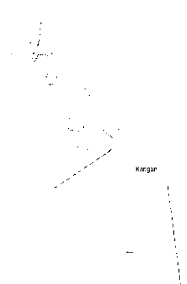

Fig. 1: Kangan city, Boushehr Province-the study area is located in

Application of Raster Images in the Present Study: The raster size is based on a database parameter that represents the length and width of a raster cell and can be changed by users. Length and width of sprayer grids are limited to multiples of this parameter. Areas of the intersections that need to be identified for an evaluation are calculated by finding the number of raster cells that intersect the derived polygons and then multiplying that number by the area of a raster grid cell [15].

In pipeline risk assessment there were some equations (Formula 1-7) for risk scoring that were to be used in determining the environmental sensitivity index and subsequently the environmental risk score for final risk assessment, including the following that were to be calculated [14] using the spatial data [3].

The data were in vector data format or stating better-shapefiles. All previous calculated cells were converted to raster type (from features) since being of feature (vector) type to be feasible of multiplication in order to calculate final risk scores. As it was mentioned previously, this was not the format of interest, so they all converted to raster types with cells of 20m due to the project situations of project-active buffer that there had been considered the most risk as the distances less than 20m from the pipeline [3]. FSR should have been computed using the values of the raster data. Since, it was rational to convert all the features into the raster form before multiplying by each other in order to obtain the FRS. As samples, figures 1-8 have been provided for respectively FES, URAS and LUS as well as IRS.

$$FES=\frac{1}{\sqrt{D}}\times 70 \quad \text{(Formula 1)}$$

$$URAS=\frac{1}{\sqrt{D}}\times 45 \quad \text{(Formula 2)}$$

$$RRS=\frac{1}{2\sqrt{P}} \quad \text{(Formula 3)}$$

$$DRS=\frac{1}{\sqrt{D}}\times 12 \quad \text{(Formula 4)}$$

$$LURS=SRS\times RRS\times DRS\times 4 \quad \text{(Formula 5)}$$

$$IRS=\sqrt{IL} \quad \text{(Formula 6)}$$

$$FRS=URAS\times FES\times LURS\times IRS \quad \text{(Formula 7)}$$

RESULTS

The obtained maps drawn finally in GIS environment were presented here as follows:

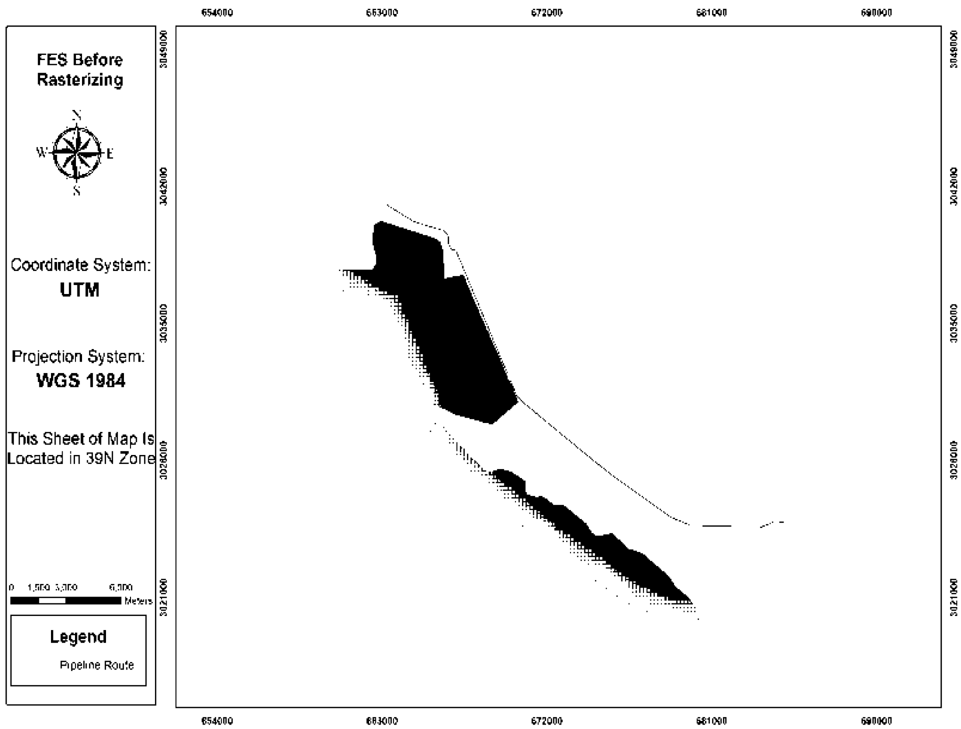

Fig. 1: FES before rasterizing

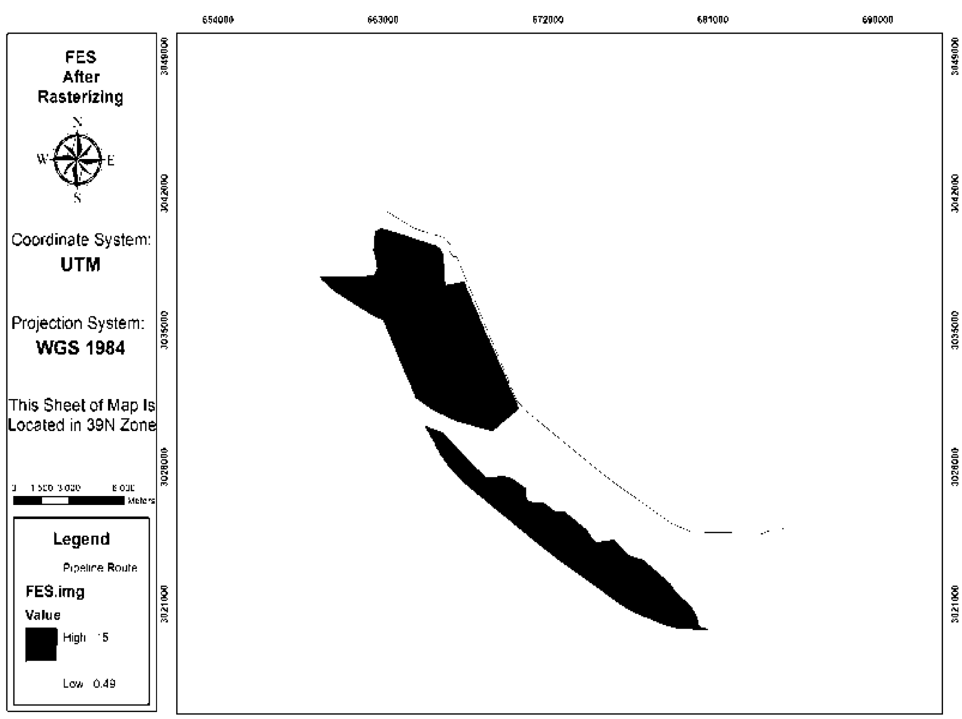

Fig. 1: FES after rasterizing

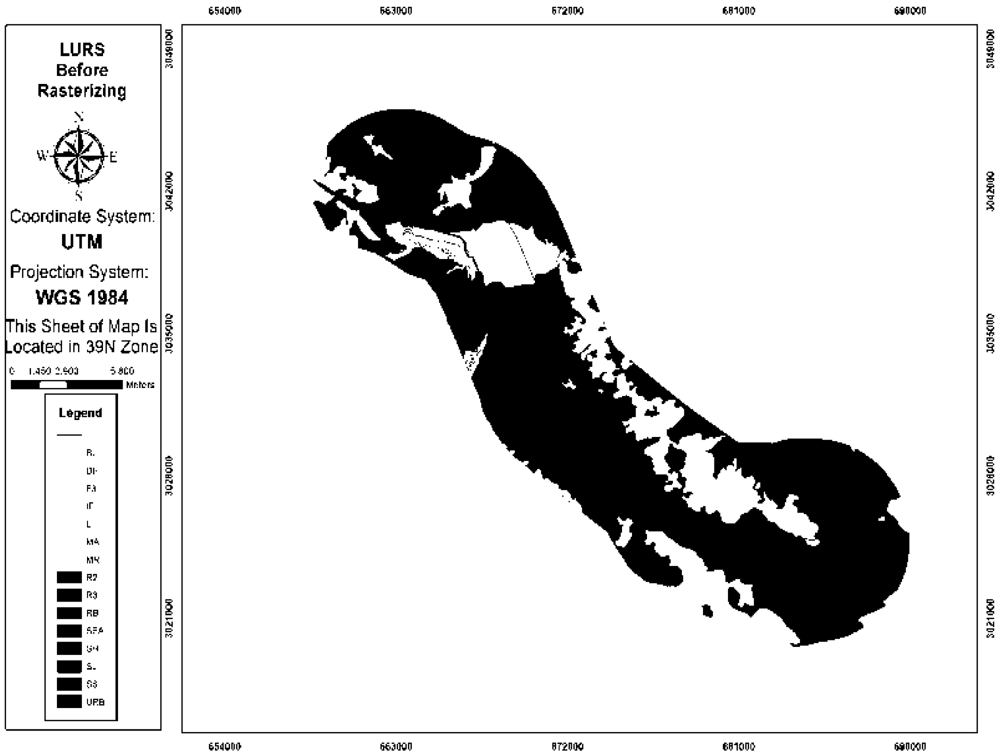

Fig. 1: LURS before rasterizing

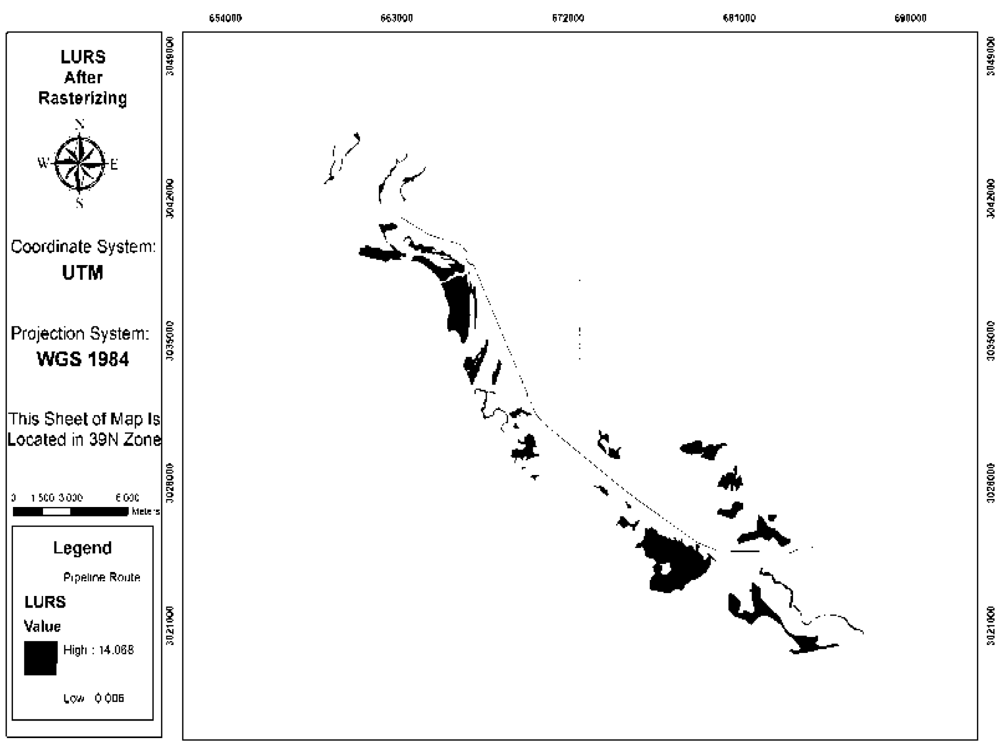

Fig. 1: LURS after rasterizing

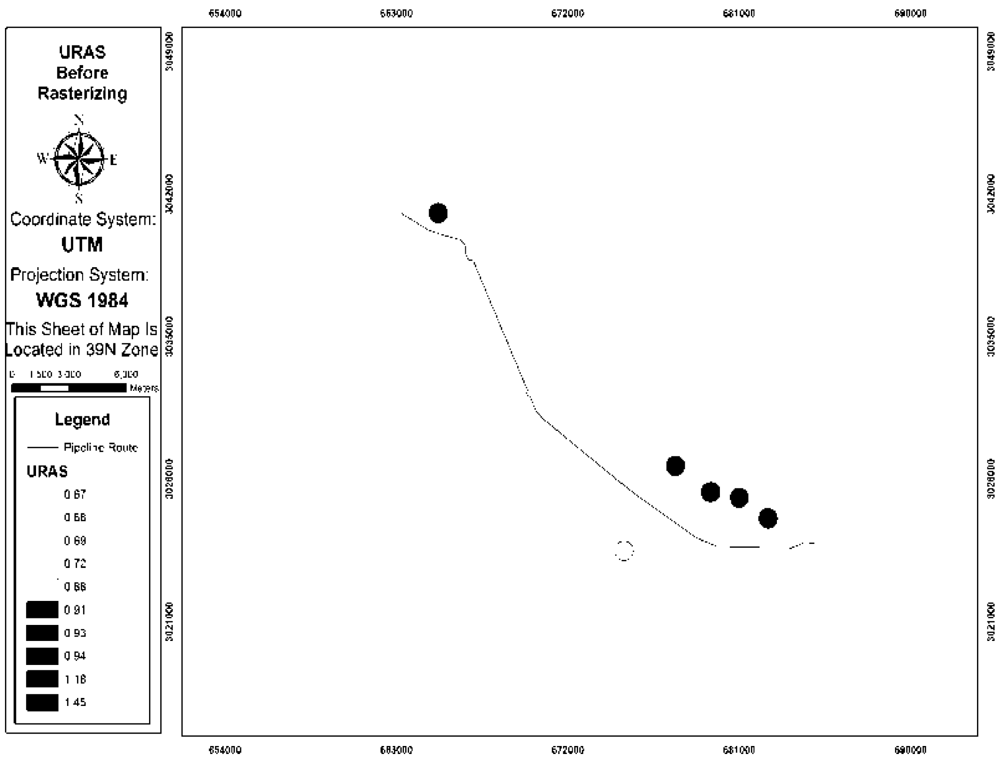

Fig. 1: URAS before rasterizing

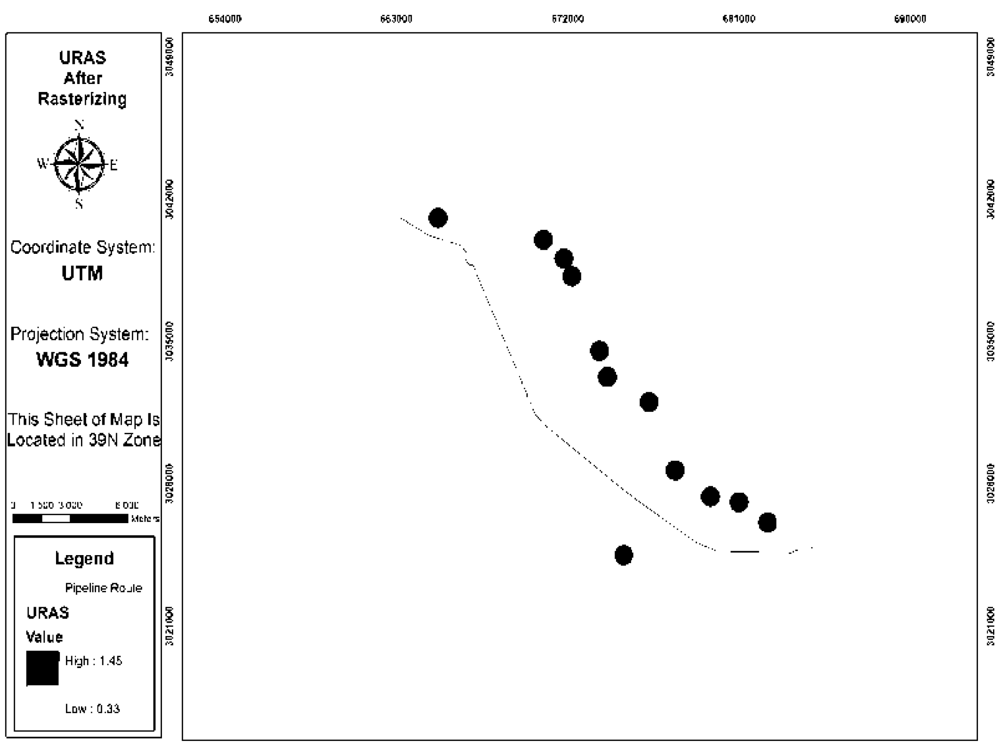

Fig. 1: URAS after rasterizing

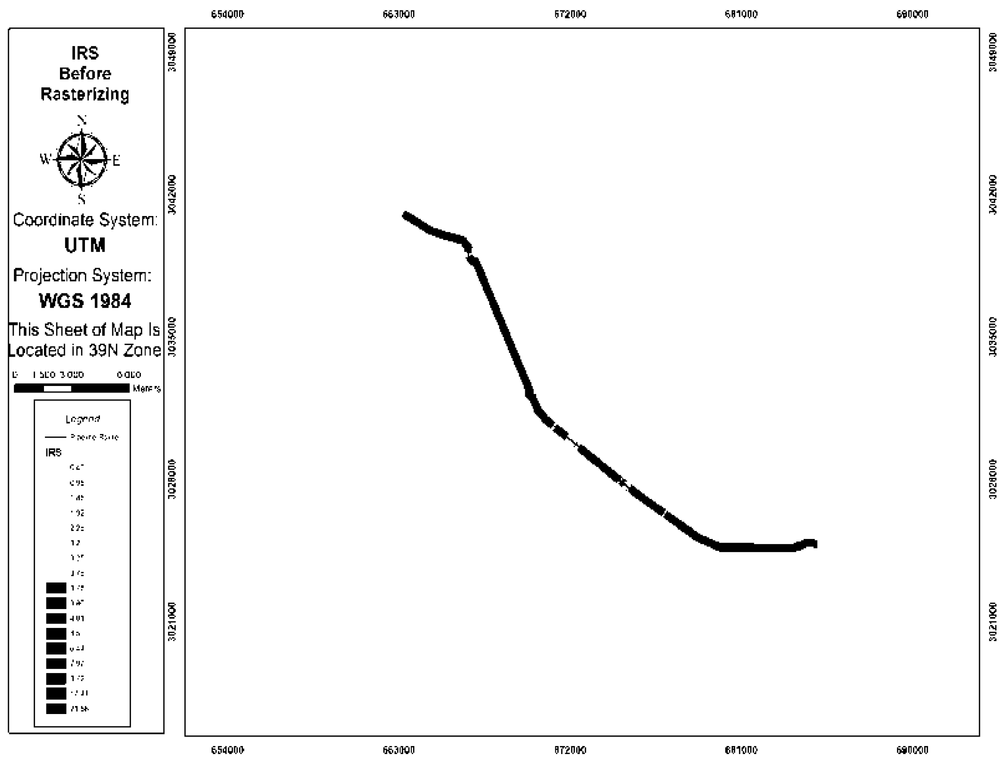

Fig. 1: IRS before rasterizing

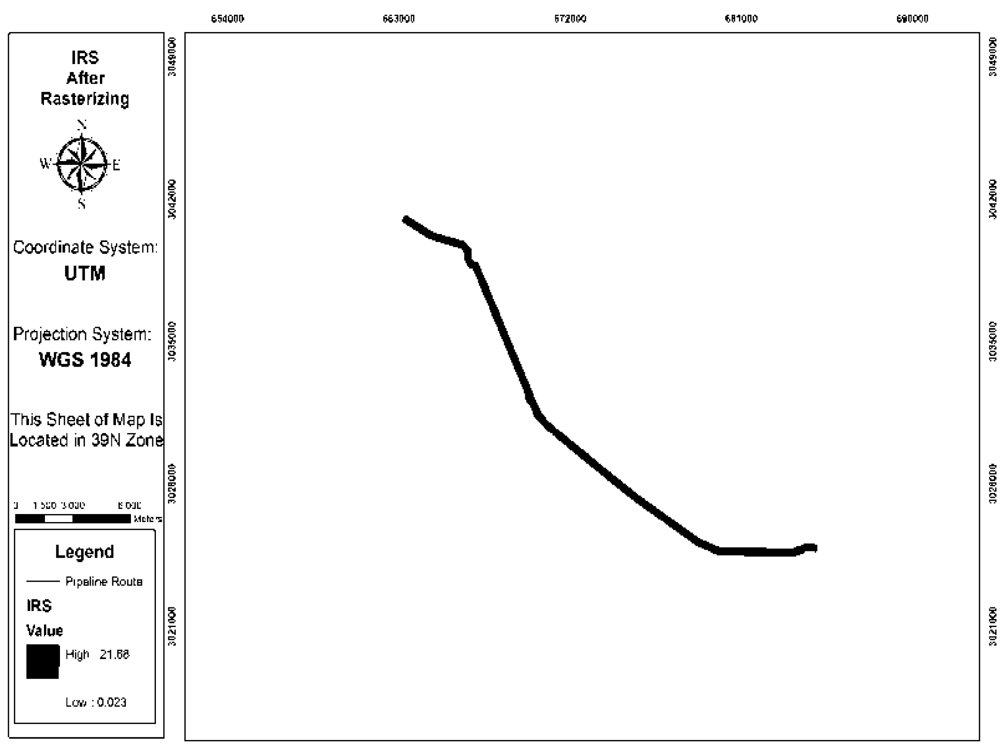

Fig. 1: IRS after rasterizing

DISCUSSION

Also in practice we see that, because of the ease with which potential values can be calculated within a raster-based GIS, the measure is often calculated by using just the geometric distances between cell centroids. As these distances are comparable to the simplest form of airline distances, the first criticism mentioned above regarding the buffer/overlay approach is in this case valid too. There is no satisfactory way in raster-based GIS to handle the effect of the discontinuous aspects of travel via a network, like multilevel overpasses and limited access to highways. Therefore, in our opinion, raster-based GIS are unsuitable for any realistic analysis involving calculations of effects of travel via transport networks [18]. Since, in pipeline risk assessment like the other type of value calculating assessments, the raster images are absolutely beneficial.

Perhaps not surprisingly it is raster-based systems that have led the way in adding statistical analysis functions to their suite of tools. Since such systems deal with data modeled as a regular tesselation (typically a square grid) there are computational advantages to be had from such data models when implemented [19]. In this direction only a grid could help us allocate the risk scores to the spatial data to get the best results from the study. With the raster data model, spatial data is not continuous but divided into discrete units. This makes raster data particularly suitable for certain types of spatial operation, for example overlays or area calculations. Users can increase raster cell size for faster, but less accurate evaluations. Evaluations would be faster and likely more accurate with an analysis of polygon intersections rather than the raster-based calculations of polygon size [15].

As previously mentioned [8] raster is a method for the storage, processing and display of spatial data. In other words, it is not convenient to store the routine data layers used to calculate risk scores in raster format, but of course it is rational to carry out what were done in this study, that is to say, convert every beneficial data layer in a reasonable way using a practical cell size for each one. For example converting the shapefile layer of land uses after putting in the procedure of calculation using raster calculator would lead in the zoning map of URAS.

CONCLUSIONS

The aim of this study was to signify the role of raster image data in computing several environmental risk scores for a pipeline that is to cross through different receptors. Based on the results of the investigations the following conclusions were drawn:

- There is an inevitable and rational practicality of raster images in order to assess the environmental risks of pipelines more accurate and precise than that of using vector-based GIS.
- Raster images should not be used for data storage in environmental risk assessment of pipelines due to the plenty of required data layers used.
- A cell size of 20m is rational for the environmental risk assessment of pipelines crossing the ecosystems not varying vastly like the case study. In those cases vastly varying due to topography and other involving factors, the cell size may be as small as 5m.
- It is suggested that new policies are to be implemented to enable geographical measures applied more precisely by making present the detailed layers of geographical data.

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REFERENCES

1. Anonymous, 2010. Pollution Probe, Clean Air, Clean Water, Environmental Risk Assessment, Environmental Concepts and Tools. Five Winds International. 2004. Page 1. Available online at: http://www.fivewinds.com/uploadedfiles_shared/EnvironmentalRiskAssessment040127.pdf. (Last accessed Jan. 2010).
2. Brazier, A.M. and R.L. Greenwood. 1998. Geographic information systems: a consistent approach to land use planning decisions around hazardous installations. Journal of Hazardous Materials, 61: 355-361.
3. Jafari, J., A. Danehkar and N. Khorasani, 2010. Environmental Sensitivity Index (ESI) as the Main Concept in Environmental Risk Assessment (ERA) of Pipelines: A Relative Semi-Quantitative Approach Based on Land Uses and HVAs. Unpublished manuscript. University of Tehran.
4. Schiller Helmut, Carlo Van Bernem and Hansjörg L. Krasemann, 2005. Automated Classification of an Environmental Sensitivity Index. Environmental Monitoring and Assessment. 110: 291-299. DOI: 10.1007/s10661-005-8041-8.

5. Mok Kang, Sang, 2002. A sensitivity analysis of the Korean composite environmental index. Ecological Economics, 43: 159-174.
6. U.S. Department of Commerce, 2008. National Oceanic and Atmospheric Administration (NOAA's National Ocean Service) Office of Response and Restoration. Anonymous Report on Environmental Sensitivity Index. http://response.restoration.noaa.gov.
7. U.S. Department of Commerce, 2008. National Oceanic and Atmospheric Administration (NOAA's National Ocean Service) Office of Response and Restoration. Environmental Sensitivity Index Mapping. October. http://response.restoration.noaa.gov.
8. Springer Recommended Reading (1). http:// www. geom.unimelb.edu.au/gisweb/ GISModule/ GIST_ Raster.htm.
9. Springer Recommended Reading (2). http://www.gsd. harvard.edu/pbcote/ courses/ gsd6322/ raster/index.htm.
10. Gregory, I.A.N., Chapter 2: The World as Viewed through a GIS. Springer Recommended Reading. http://ahds.ac.uk/history/creating/guides/gis/.
11. Harvey, Francis, 2008. A Primer of Gis Fundamental Geographicand Cartographic Concepts. The Guilford Press: New York.
12. Lodwick, Weldon (Ed), 2008. Fuzzy Surfaces in GIS and Geographical Analysis Theory, Analytical Methods, Algorithms and Applications. CRC Press, Taylor and Francis Group: New York.
13. Köhl, Michael, Steen Magnussen and Marco Marchetti, 2006. Sampling Methods, Remote Sensing and GIS Multiresource Forest Inventory. Springer: Verlag Berlin Heidelberg.
14. Skidmore Andrew (Ed), K., 2003. Environmental Modelling with GIS and Remote Sensing, Chapter 8: Biodiversity mapping and modelling. CRC Press, Taylor and Francis Group: New York.
15. Pierce, J. Francis and David Clay (Eds), 2007. GIS Applications in Agriculture. CRC Press, Taylor and Francis Group: New York.
16. Savitsky, G., Basil and Thomas E. Lacher, 1998. GIS Methodologies for Developing Conservation Strategies: Tropical Forest Recovery and Wildlife Management in Costa Rica. Columbia University Press: New York.
17. Abdul-Rahman, Alias and Morakot Pilouk, 2008. Spatial Data Modelling for 3D GIS. Springer: Verlag Berlin Heidelberg.
18. Stillwell, John and Graham Clarke (Eds), 2004. Applied GIS and Spatial Analysis. John Wiley and Sons: West Sussex, England.
19. Fotheringham, Stewart and and Peter Rogerson, 2005. Spatial analysis and GIS. Taylor and Francis: London.