جامعة الملك فهد للبترول والمعادن
King Fahd University of Petroleum & Minerals

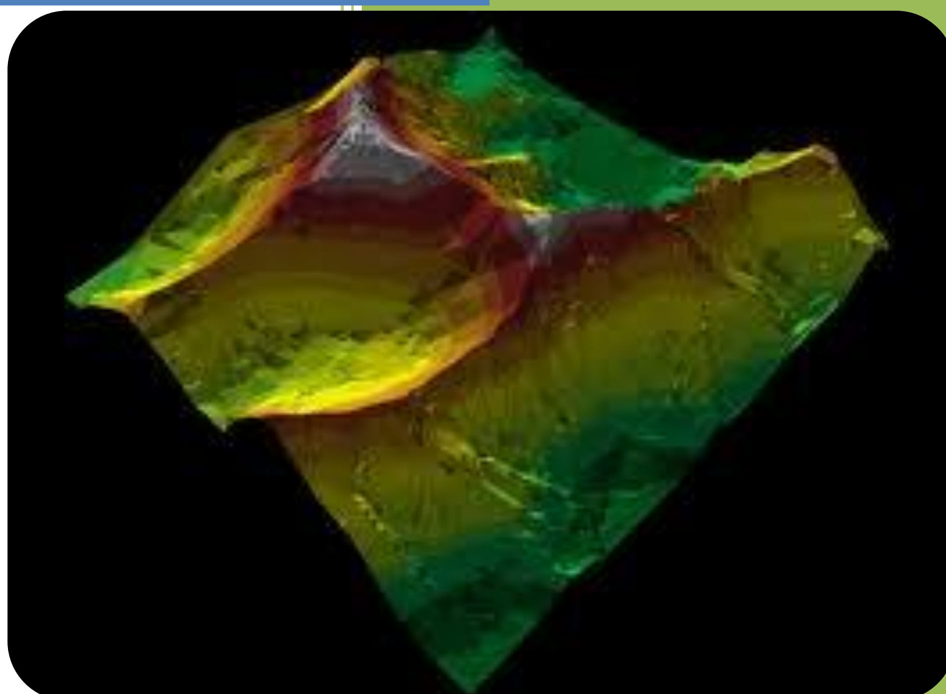
TERM PAPER

Department of City and Regional Planning

CRP 514: INTRODUCTION to GIS

GIS in the Petroleum Industry

An Exploration and Exploitation Tool



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1. Introduction:

The geographic information system (GIS) is a tremendous tool, which can be very helpful when it comes to problem solving process encountered by exploration and exploitation operations.

Spatial information is the key element in the petroleum industry, from the initial permission, exploration, through appraisal, production and abandon phase, implying that most of the data used in this industry has spatial component can be accessed though a map or connected to a location.

Petroleum Exploration as major phase in the petroleum industry, requires analysis of considerable and various types of data such as digital aerial photo, satellite imagery, seismic surveys, subsurface and surface geology, well location and many more, the GIS can tie or linked these data together with the location in question, allowing to overlay, view, and manipulate the data to fully analyze the potentiality of an oil field or finding new potential fields.

On the other hand exploitation evaluation conventionally transact with much larger datasets than those utilized in the exploration operations.

2. Literature review:

2.1 Historical background;

The develop of the GIS embark with the rise of the computer-based mapping technology back in the early 1960s, by 1990s the prevalent of the UNIX workstations and personal computers fairly import the GIS technology to desktop computer users.

The 1990s also considered the birth period of using GIS technology in the petroleum industry, the first ESRI petroleum user group led by companies like EXXON and SHEL had met the early 1990s. Toward the end of 1990s companies such as Landmark and Schlumberger (oil and service companies) were starting to support their commercial software products with GIS technology.

The 2000s witnessed advances in the internet mapping, which allow the GIS data and analysis to be compiled by an expert using desktop GIS, and consequently distributed to wider userbase by internet technology. In the Petroleum industry this era introduce the GIS use to other operational areas, such as facilities management, production, and HSE (After ESRI press).

2.2 Application of GIS in Petroleum Industry;

The Geographic information system can be adopted in various phases of the petroleum industry, which in turn can be categorized into two main parts, the exploration part, and the exploitation part, and the last concerned with the production, development, pipeline routing, managements, and distribution. The exact procedures and applications of the GIS will differ according to the task or the project and to a far extent on the type and the size of the datasets or the data base implicated (Barrell, 2000).

2.2.1The Application in the Petroleum Exploration;

GIS is a credible tool in the exploration of the petroleum, especially when it comes to the exploration mapping or reconnaissance mapping. The mapping is frequently preformed over wide geographic areas, involving many map layers and data sets which utilized in the analysis of the hydrocarbons. Also the raster data for example, the satellite imagery or aerial photos, can be integrated with vector data like the topographic control points, elevations contours or any points of particular interest. There is abundant of maps and map layers of even greater number of features must be included in the preliminary phases of any exploration reconnaissance mapping such as;

- Well locations and total depths
- Completion date and well classification
- Producing reservoirs
- Initial Hydrocarbon potential
- Cumulative production

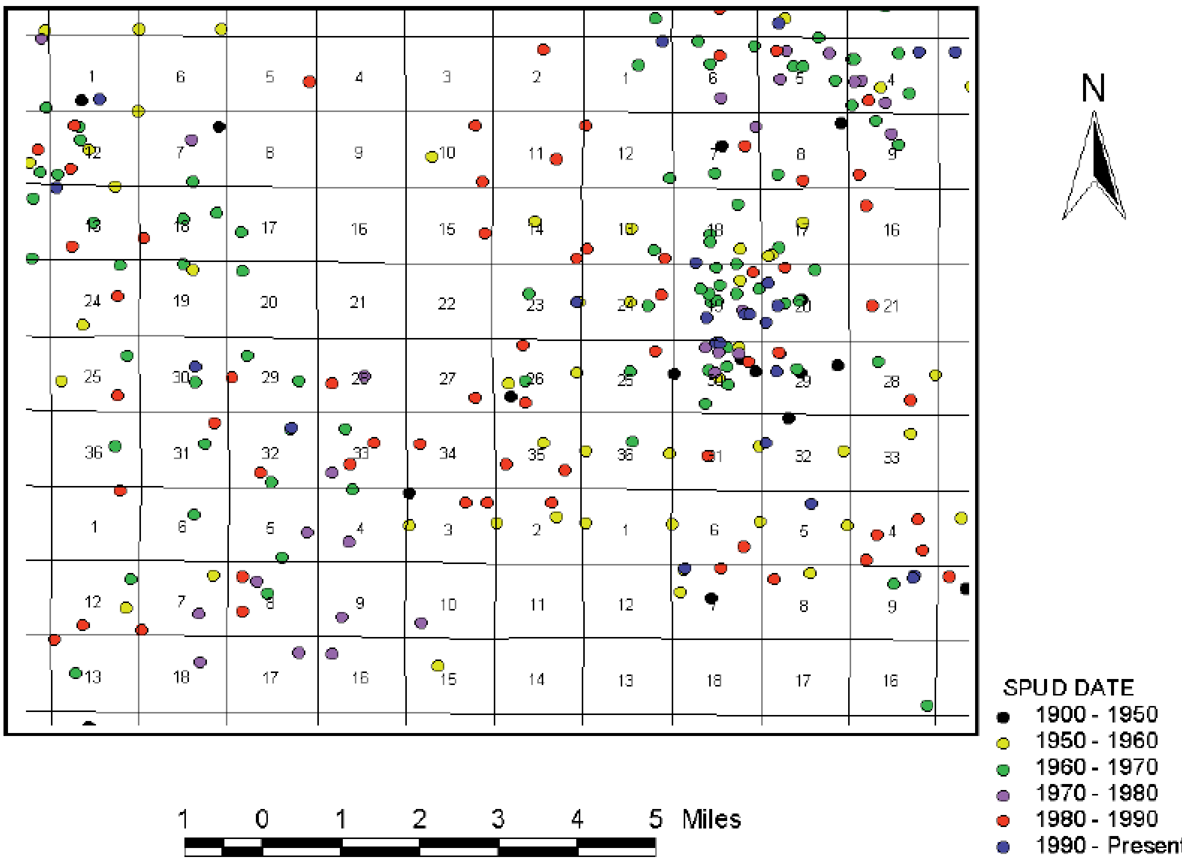


Fig. 1: Northern Louisiana base map of wells classified by spud drilled date (after Barrell, 2000)

The produced maps can be adopted when evaluating a new basins or provenance, and to find out which geologic member or formation produces Hydrocarbons and where the production is located. Consequently the producing zones or formations can assigned names or codes in the database and then could be symbolized or mapped (Barrell, 2000).

This brief posed implies that the GIS can be a valuable exploration tool at different variety such as the basins, trends, or field levels, and the mean reason is that the GIS is not restricted to specific geographic area or even bounded to a map scale (Barrell, 2000).

2.2.2 The Application in the Petroleum Exploitation;

This part of the petroleum industry conventionally deals with much bigger datasets or databases than those utilized in the exploration part. This approach is mainly applied to mature producing fields where the well controls are denser. GIS can be absolutely useful in this environment as multiple types of maps on different horizons are basically required, and information from various databases can be integrated. In this approach GIS would be more than a tool for mapping, because it can introduce an influential database management tool.

Overlaying and integration of multiple types of maps is essential in the exploration settings. Fig.2 shows a map in southern Louisiana in which three different data layers had been integrated; well location, fault location, and structures on top of the Camerina sand.

In addition GIS technology is a very useful tool for extending the geoscientist's capabilities far outside the conventional geological mapping based on hard copies of maps.

Sand isopach map is another kind of maps that normally used in the exploitation. Fig.3 shows a typical map created utilizing GIS, which integration of three map layers; contours of sand isopach map, well locations map, and faults location maps. By using this kind of maps the relationships between the wells and the sand isopach can be easily evaluated. In this case we can find that the integration between the three maps is not only direct but its repeatable, which leads to more productive usage of the analyst's time compared with that does the conventional mapping methods.

Furthermore, the assessment of the reservoir drainage area and volume is an importat phase of the of the exploitation processes. Fig.4 shows gas field map constructed on 40 acre spacing by using GIS to create buffers, or rounded rings around the wells. Producing this kind of maps, the well intervals can be estimated to determine if the reservoir is producing efficiently.

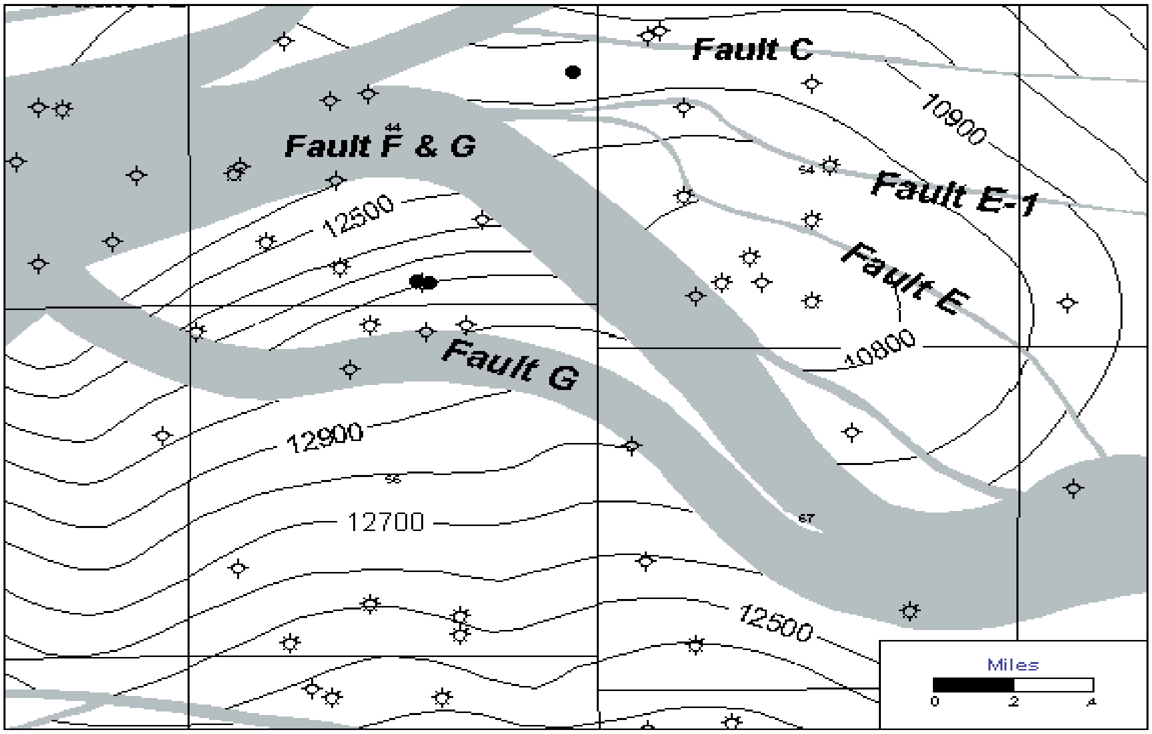


Fig.2: Southern Louisiana structure map on the Camerina sand (after Barrell, 2000)

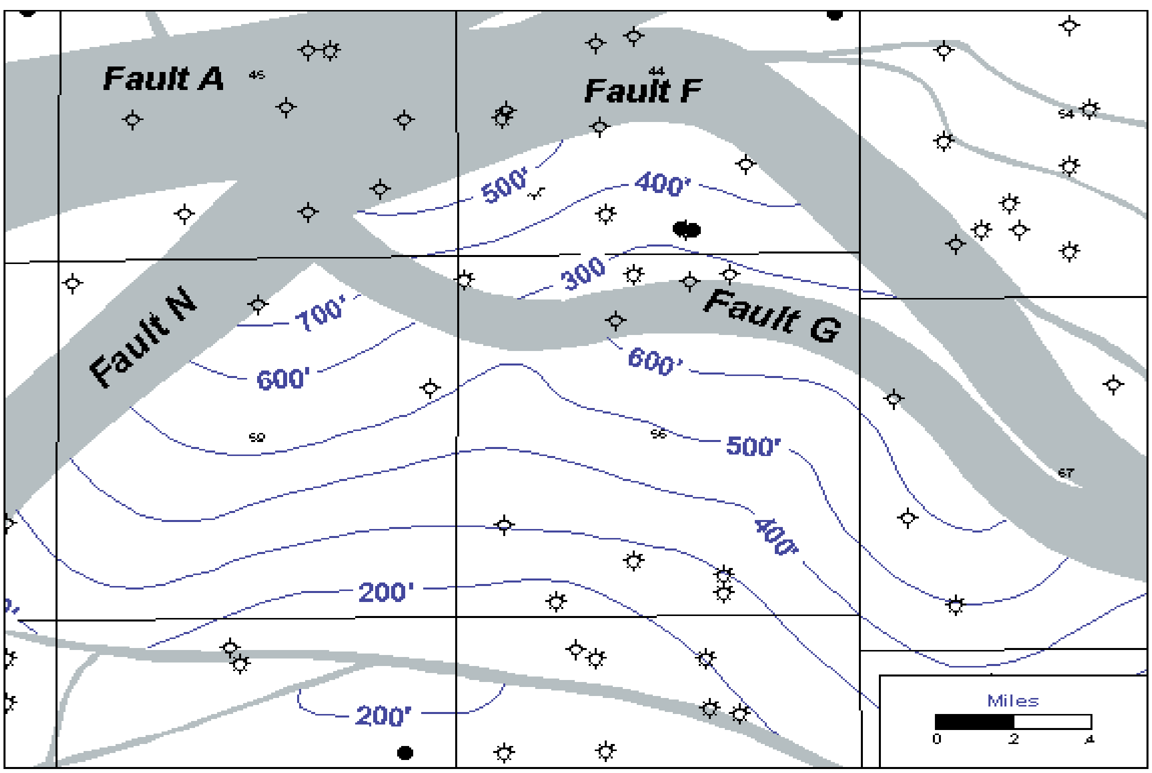


Fig.3: Isopach map Southern Louisiana map on the Camerina sand (after Barrell, 2000)

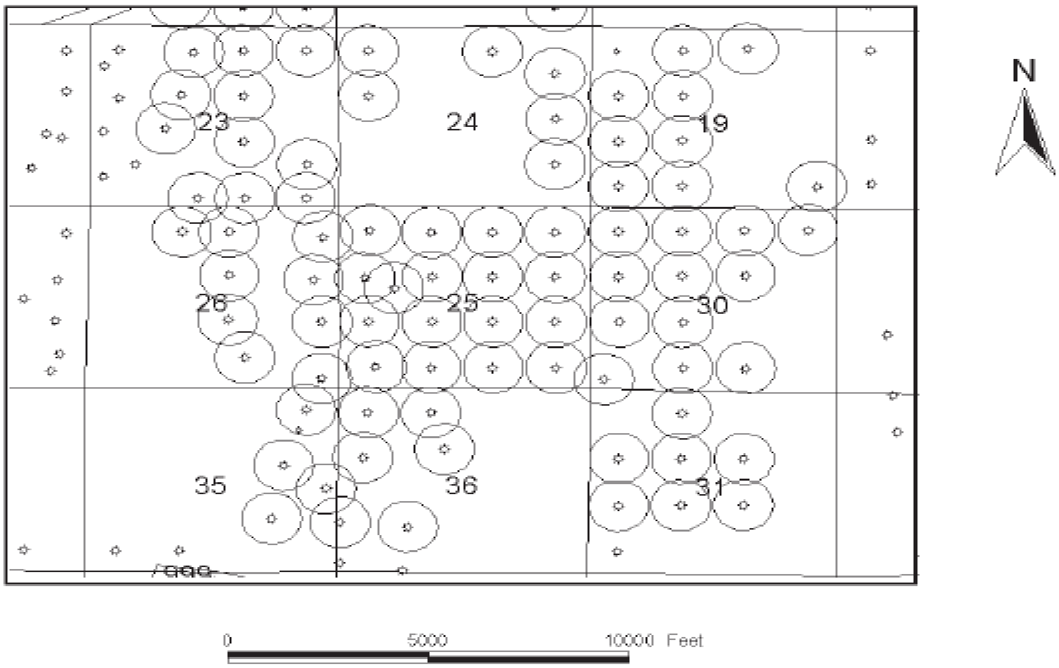


Fig.4: Wells map of Northern Louisiana base showing 40 acre drainage buffers (after Barrell, 2000)

3. Work Scope:

This paper will investigate and discuss the importance and contribution of the Geographic Information System (GIS) in the Petroleum industry. Utilizing the role of GIS in handling complex spatial data encountered in this industry, and how it can help in better decision making. By illuminating the contributions which GIS can offer in three stages of the industry:

1) The exploration phase;

   In order to manage, analysis and integrate all the data comes from verity of source such as geological maps, seismic and gravity surveys, well location, and so on

2) The production phase;

   To handle much more critical data regarding the field production management

3) The pipeline routing;

   This is major part of petroleum exploitation beside production phase. In which description is made of how the GIS will facilitate the site location process to reduce the impacts on the environment, cost and distance consuming, risk associated with construction and accidental release or seeping.

4. Methodology:

This paper will concentrate on discussing the utilizing of GIS in the main two phases of the petroleum industry. In this In order to fulfill the objectives of this study a detailed reviewing of case studies is accomplished. And in this approach two case studies have been selected.

5. Case study 1:

<u>Oil and Gas in Ethiopia Using GIS</u>

In this study the GIS had been used by PETRONAS OIL CO. for planning it is project of exploration of oil and gas in Ethiopia. Integrated geological maps had been developed by using different data types, such as digital elevation models, topographical maps, faults and folds, satellite images, strike and dip maps, leads and prospect maps, lithology maps to state the possibility to explore oil and gas, subsequently GIS was applied the best seismic line layout for exploration purpose, which result in decreasing cost and time consumed.

5.1 GIS in PETRONAS:

PETRONAS in 2005 started Enterprise GIS Petroleum Management Unit (PMU), with main objectives in centralizing geospatial database to support the exploration and production business within domestic and international operations. Laterally PMU and PCOSB worked together in order to using GIS in the seismic survey in Ethiopia planning and decision making. With GIS offering huge ability in handling spatial database and coordinate reliability through ArcGis, the planning of seismic advanced leading to time consumption and reflects the data quality during operations.

5.2 Geological background and project challenges:

Ethiopia is situated in the southern Red Sea region in eastern Africa. Topographically Ethiopia consists of central high plateau which divided the Ethiopian segment of the Great Rift Valley into southern and northern highlands and bounded by lowlands. The PCOBS fields are located in the east and southeast area, which belong to the semi desert area. There are three significant geographical terrains that consist of mountains, plains and hills which make the field operations inconvenient. The rock layers and big pieces of rocks, stones and gravels are commonly observed scattered on the surface indicating that the soil cover is very thin (between 0.5 to 1 meter), and overlaying the bedrocks or big boulders. The Genale River runs across the western block through the year. The climate is semi arid which is mean the rainfall is very little extending from April till October (Abdlatef and Khar, 2008).

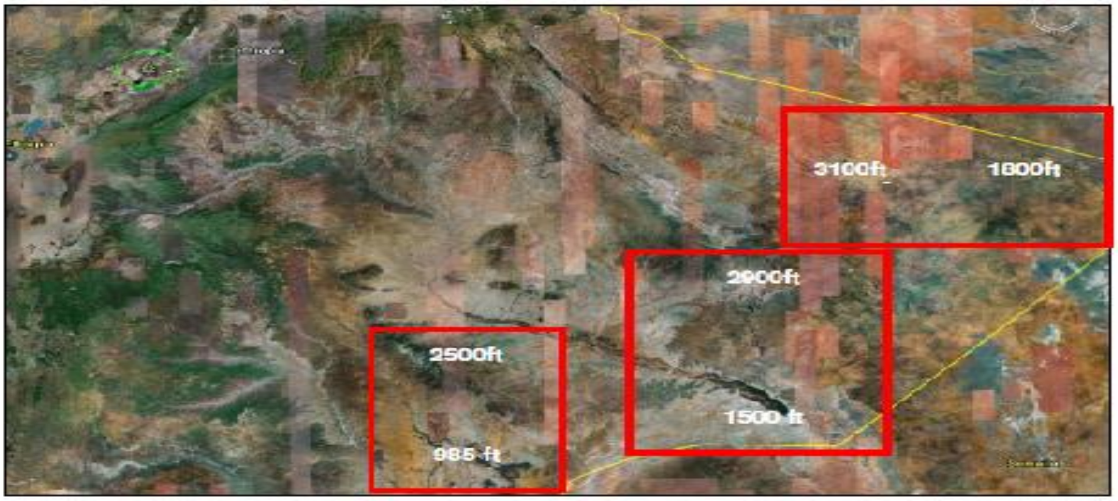


Fig.5: Topographic surface map of PCOBS areas as a satellite image (after Abdlatef and Khar, 2008)

Fig.6: Example of terrain variation in the area from rough to flat lands (after Abdlatef and Khar, 2008)

This climate and topographical parameters introduced several challenges to the seismic survey projects in Ethiopia summarized in the following;

- The access to the blocks and facilities are is limited due to rugged topography and this has its implication on seismic survey lines planning.

- Awkwardness in estimating and measuring the best route for the lines of the survey and that's reflected on poor data of the subsurface
- Health and safety matters (HSE)

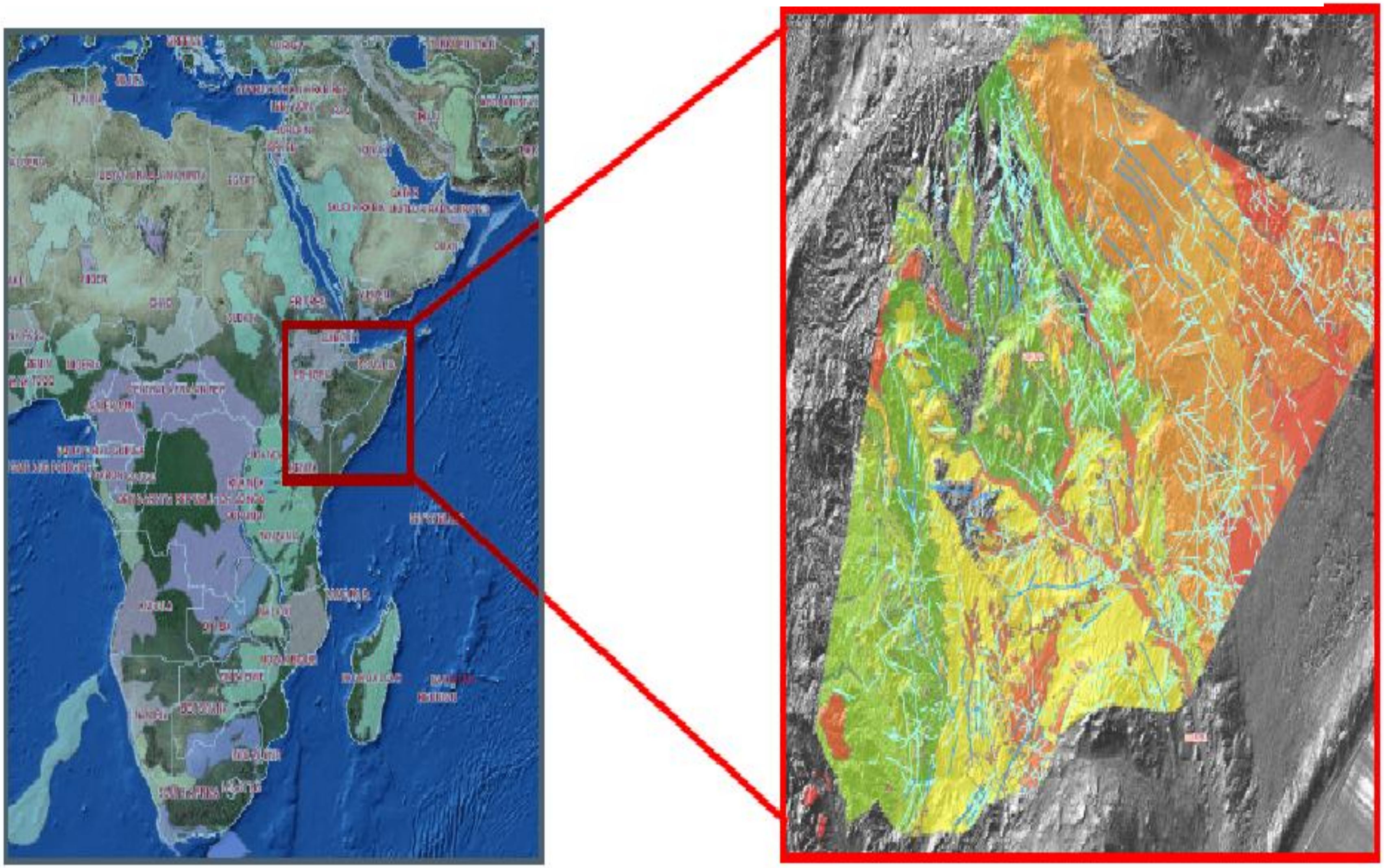
ArcGIS was then used to map the area by incorporating various datasets and map layers to develop an enhanced picture, and much better ease.

5.3 Regional Geological Mapping using GIS:

Geological data was collected from the previous studies in the field blocks. Through this process the targeted areas will be evaluated via reevaluating and comparing the potential targets. During the procedure of evaluating the geological structural map of the area, integrated geological maps were created. This operation combined the gravity and magnetic survey maps with the DEM and topography overlays. These maps were to image the shape of the sedimentary basin, plays, prospects and leads (Abdlatef and Khar, 2008).

All the maps were generated from different sources categorized into either digital formats or hardcopies. The hardcopies were geo-referenced and overlaid with other datasets into a single coordinate system. The capability of the ArcGIS in incorporating the data played a significant role in time reduction and resolving some of the complexity such as the uncertainty of the geo-referencing and misallocated data sources, etc. Fig. 7.

Fig.7: Regional geological mapping in the study area (Ethiopia) using ArcGis, (after Abdlatef & Khar, 2008)



5.4 Seismic survey planning:

In the seismic survey data acquisition and before the shooting and recording the first survey line geophysicist must decide the optimum survey path in order to reveal the targets in the subsurface. In general, geophysicists also take into account the locations, type of energy source and receivers as well as time and labors. And addition factors like HSE issue required achieving the acquisition. This factor may include:

- The prevailing topography: because the seismic survey line must be straight as possible. And the flatness of the topography also must be taken into account.
- HSE issues: Health and Safety matters must be considers as a priorities
- Subsurface features and Structures: must be handled with great care, for example:
    a. Must follow the dipping structures for the Inline Seismic. Fig.8-A
    b. And follow the strike lines of the structures in the Cross Seismic to obtain precise seismic reflection data. Fig. 8-B

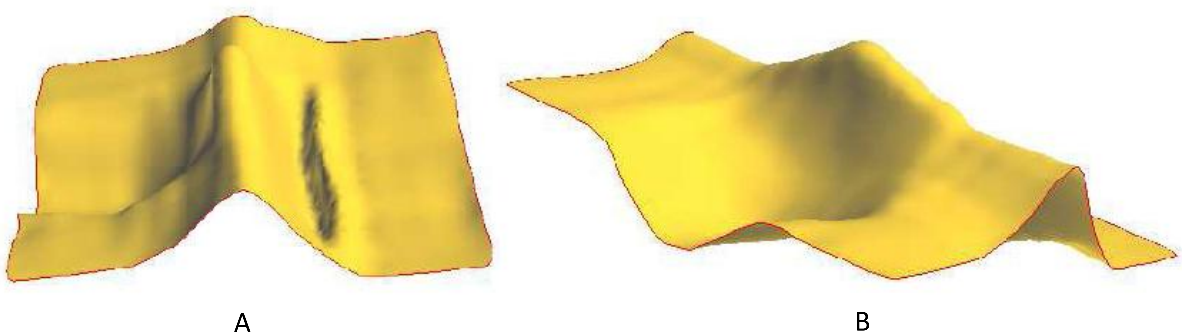


Fig.8: DEM for determination of seismic 3D lines (conceptual of inline {A} and cross line {B}) (after Abdlatef and Khar, 2008)

Those factors and to afar extent affect on the survey lines determinations. For example, on the western blocks, there is a rough topography (surface) ranging between 160m to 1500m, this topography disrupts the planned straight from the bottom to the block end. This disruption can be determined by visualizing the topographical surfaces from the Hillshade and Digital Elevation Model of the block area, Fig.9.

Relying on the integration and visualizing of datasets using ArcGIS, the geophysicist can shift the survey seismic line to their new optimum location. This process result in improving of the knowing the survey area and effectively reduce the time consumed in accessing and dropping the seismic sources during an acquisition operation (Abdlatef and Khar, 2008).

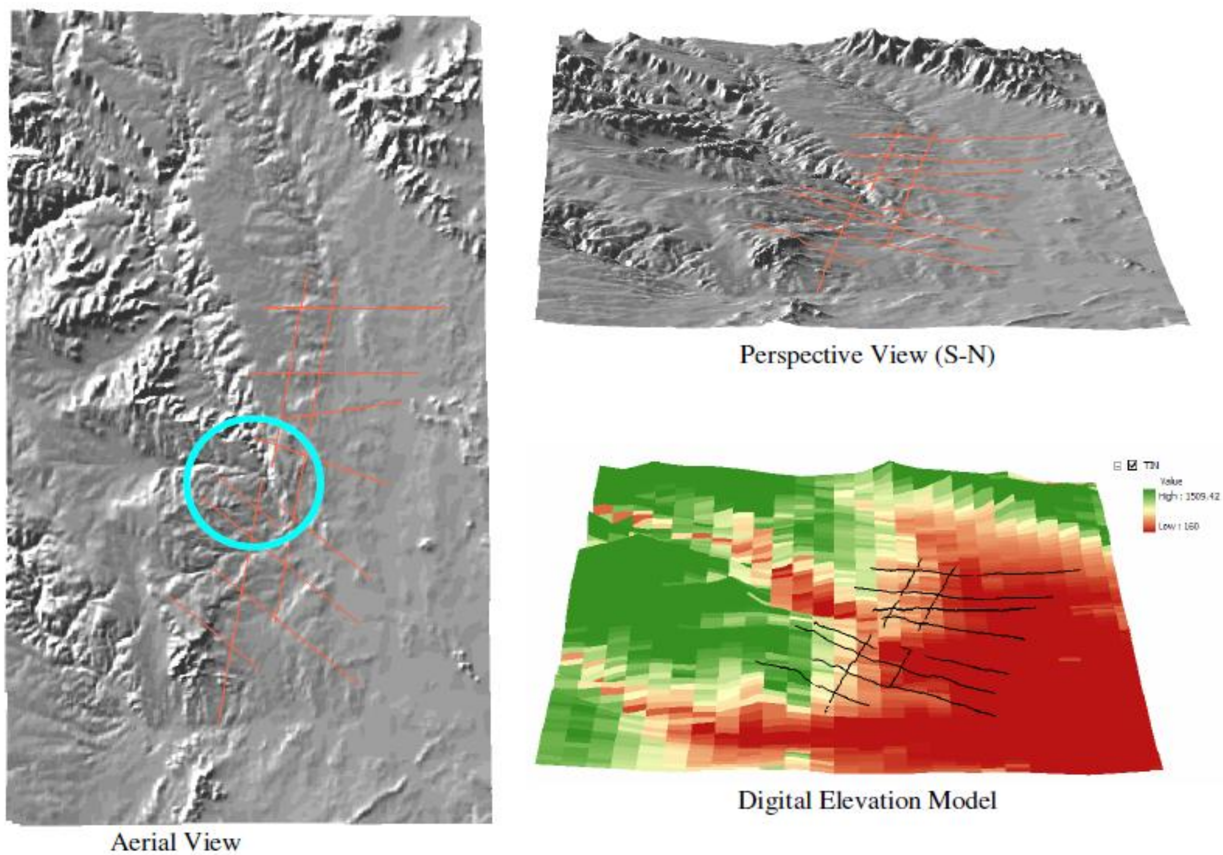


Fig. 9: The topographical analysis of the study area using ArcGIS_3D (after Abdlatef and Khar, 2008)

5.5 Integrated Geological maps:

The exploration phase involves analysis and management of a bundle and varies kind of data like Seismic survey maps, DEM, surface geology maps, satellite imagery, well locations, and so much more. GIS is able to integrate these sets of data and tie them to the desired location. In addition GIS offer the flexibility to overlay, view and also manipulate the data.

First multi disciplinary surveys were accomplished in the country. According to these surveys multiple locations were agreed on according to:

1) From the satellite imagery and aerial photos, surface lineaments and accurate anomalies have been identified.
2) Graphical representation and analysis of the fracture and their orientation, density and lengths.
3) Regional geology and geophysical components.
4) Analysis and Mapping of the area with;
    - Older Structures through 2D and 3D surveys, and
    - Topography for the accessibility purposes.

Initially by the integration of the datasets using GIS, the raster data like the satellite imageries and the aerial photos can be combined with the vector data. Also it can be incorporated with surface culture like the topographic pinch marks, contours; DEM models and so on (Fig.10).

The following characteristics and features maps were generated at the first phase of reconnaissance mapping program:

- Topographic map inclusive DEM and satellite images
- Ethiopia cultural maps from the internal datasets and public data
- Geophysical maps including magnetic, gravity and geology
- Seismic survey maps including 2D and 3D

5.6 Benefits of Using GIS in Ethiopia Project:

The benefits of exploiting GIS in Ethiopia Project can be summarized as follows:

1) Time consumed in designing seismic survey by;
    - Planning the optimum routes of seismic direction from DEM, topographic maps, and satellite images.
    - Resolving the coordinates issues encountered in ArcGIS, GeogCRS, and ProjCRS
2) Costs savings:
    - From the designing of seismic survey
3) Incorporation the contribution of various crews through multi-disciplinary integration and software.

4) Providing new methods into visualizing through symbology utilizing.
5) Presentation of the data in different forms like maps, queries, charts, tables, etc.
6) Connecting multiple applications software and formats.
7) Archiving the whole project data into centralized GIS database (GEODATABASE).
8) Digital databases dynamic mapping.

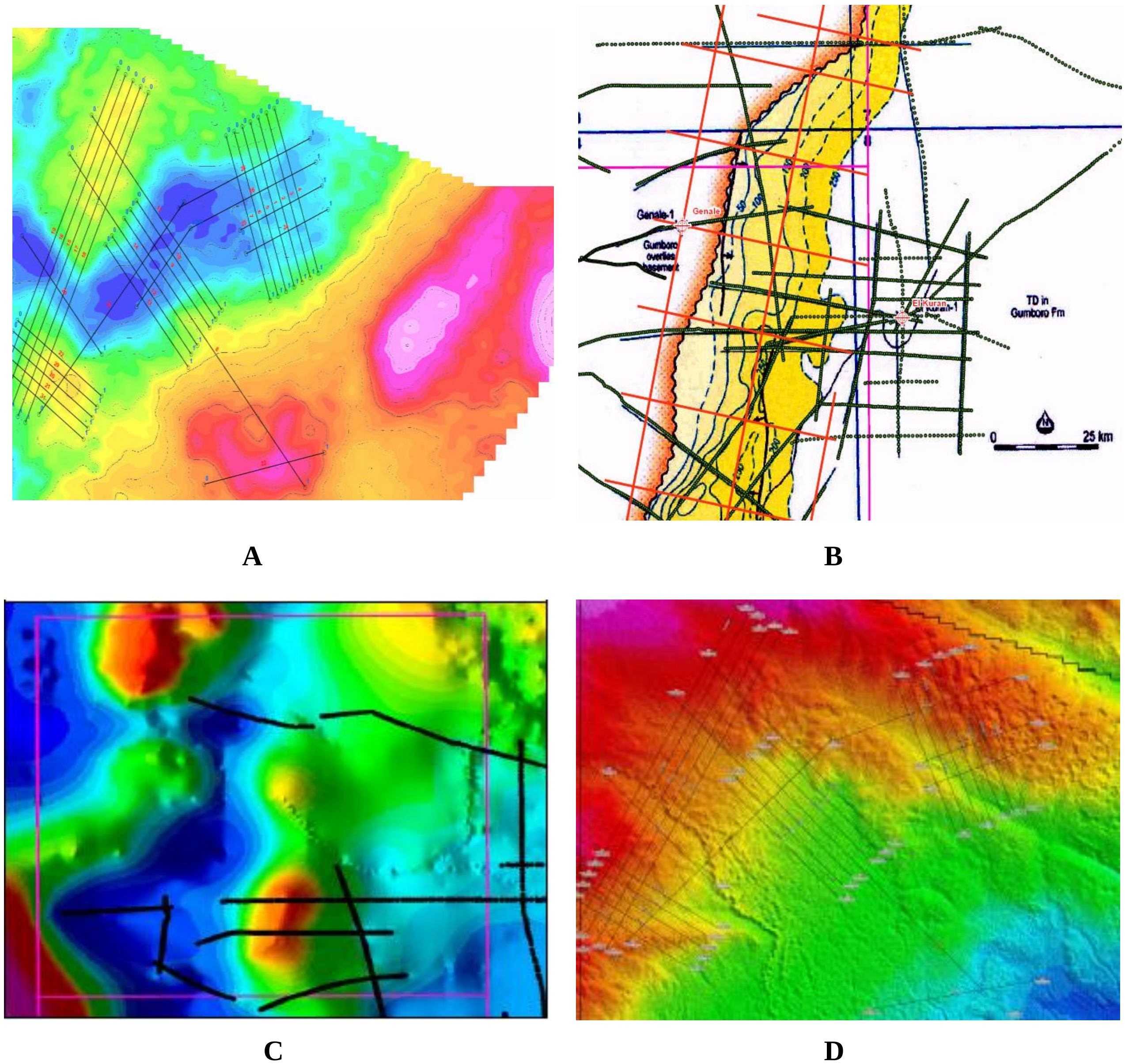


Fig. 10: The maps of the feature created during the reconnaissance phase. (A) The gravity maps with seismic lines, (B) seismic overlay map with the subsurface, (C) the magnetic map with seismic lines, (D) topographic map (SRTM). (After Abdlatef and Khar, 2008)

6. Case study 2:

Optimal Oil Pipeline Route Selection using GIS: Community Participation in Weight derivation and Disaster Mitigation

GIS technology have been profitably adopted in pipeline routing operations, by integration thoughts of local neighborhood members in weight derivation/ranking the variables, we are managed to come out with rational and trustworthy pipe route which meets all the aspirations of the concerned parties.

This paper represent first stair towards incorporation of GIS and multi criteria decision analysis (MCDA) in pipeline route optimal selection. (Balogun et al, 2012)

6.1 Pipeline Route Selection Using GIS:

GIS Technology has a great importance in the oil and gas industry is as an indispensable tool capable of helping the decision makers in order to select the best route for the new pipeline. These potentialities offered by GIS leads to minimizing the environmental impacts during constructions, as well as reducing the project the overall budget. In this kind of project, there are several parameters are usually utilized as input in the spatial process. Some of them include the following;

- Shortest distance from field to markets
- Least grading
- The slope of topography
- Subsurface geology (pipeline protection)
- Proximity to residents centers
- Cost encountered with the land right indemnity.

Beside these fully known and often used parameters, the next four variables were utilized as inputs in this project

1. evasion of prawn areas

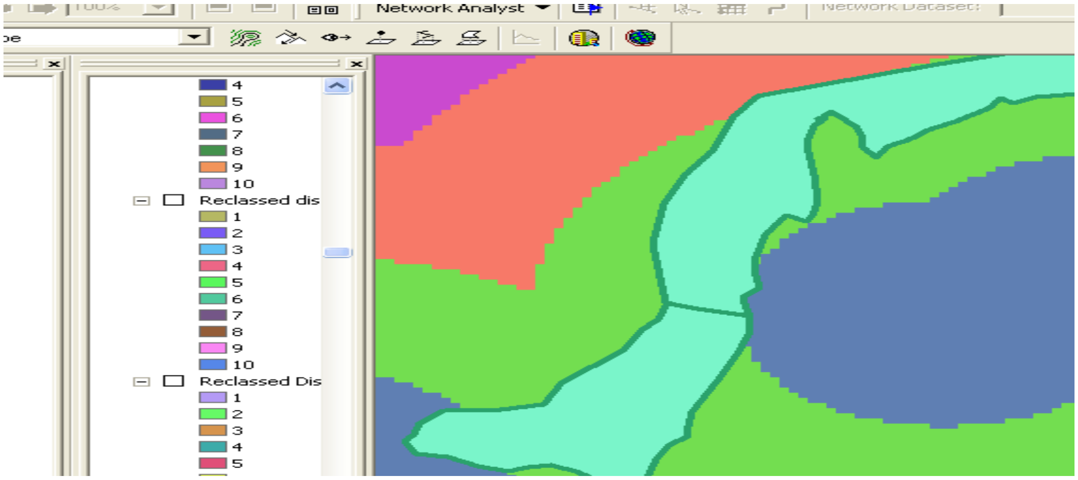


Fig.11: prawn areas that must be dodged by the pipe line (after Balogun et al, 2012)

2. evasion of Aquaculture areas

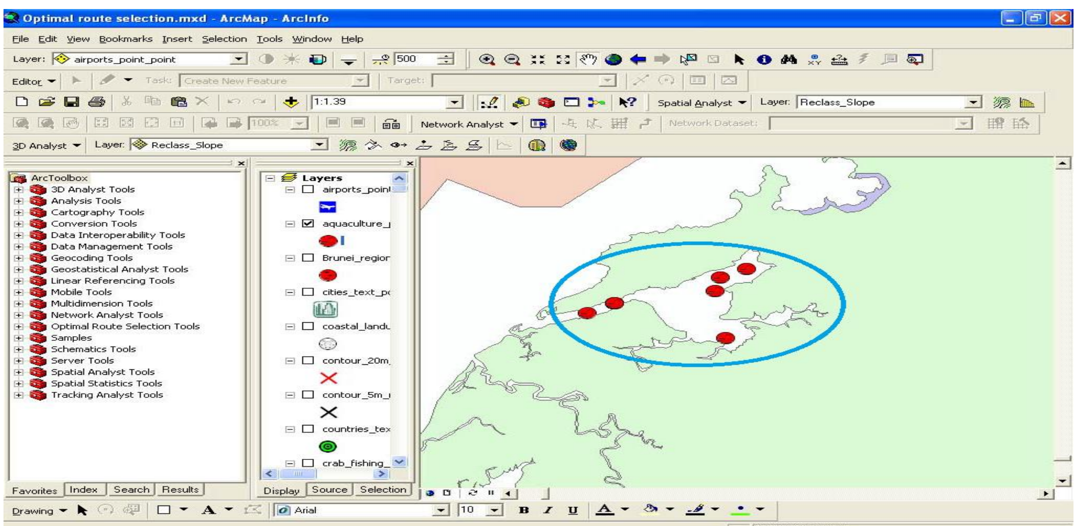


Fig. 12: Aquaculture areas that must be dodged by the pipe line (after Balogun et al, 2012)

3. Proximity to Airport:

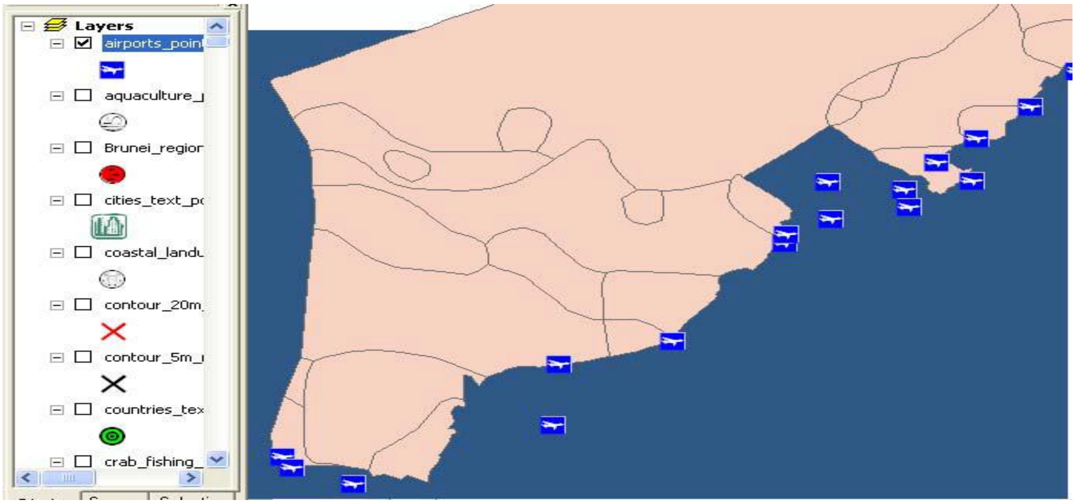


Fig. 13: Airport regions that must be bypass within the study are by pipeline (after Balogun et al, 2012)

4. Proximity to accessible roads:

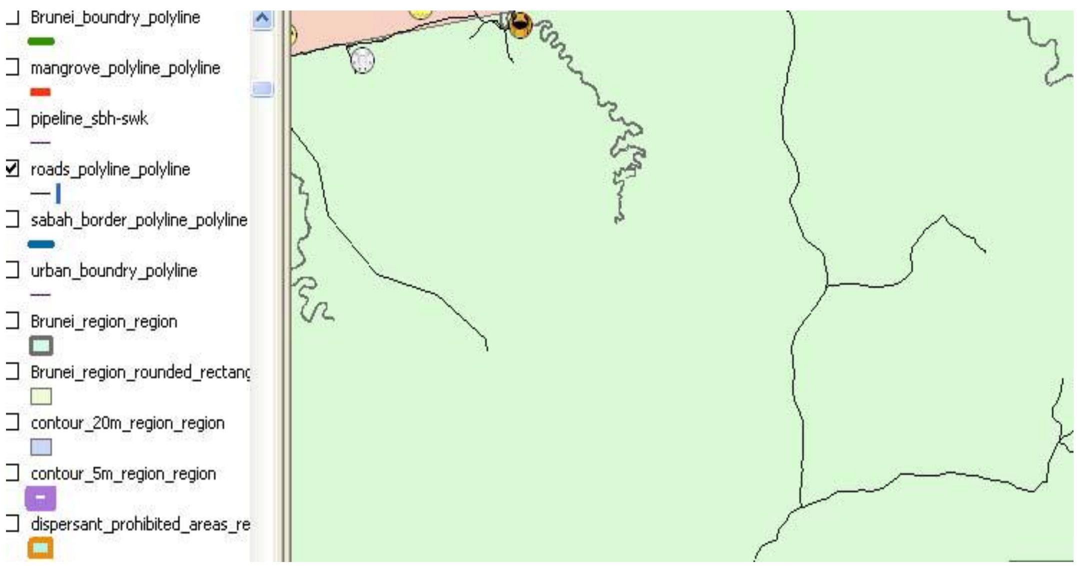


Fig. 14: The route must be closed to these roads (after Balogun et al, 2012)

6.2 Methodology for Creating the Route:

There are numbers of steps were taken in order to create the best possible route for the pipeline, which can be summarized in the following:

A. Rasteraization of vector maps
B. Reclassifications
C. Weighting of routing criteria
D. Generation of Suitability Map
E. Determination of the best and optimal route according t produced weighted raster

In order to perform this operation ArcGIS 9.2 Spatial Analyst was utilized. Hence the tools in the spatial analyst are designed for usage of Thematic Raster Data; the obtained Vector Data must convert to the Raster format via rasterization. Then, using the reclassification process to merge all the rasterized parameters into a single shape file (layer), and also converting them from their individual scale to a combined scale. As shown in (fig. 15) below.

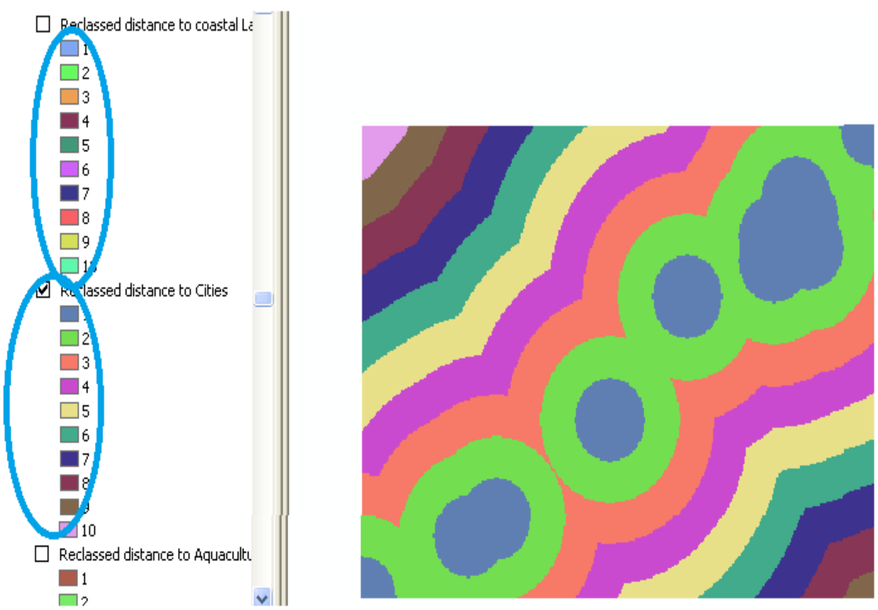


Fig. 15: Data Reclassification; reclassified data layer to represent a populated center (town) (after Balogun et al, 2012)

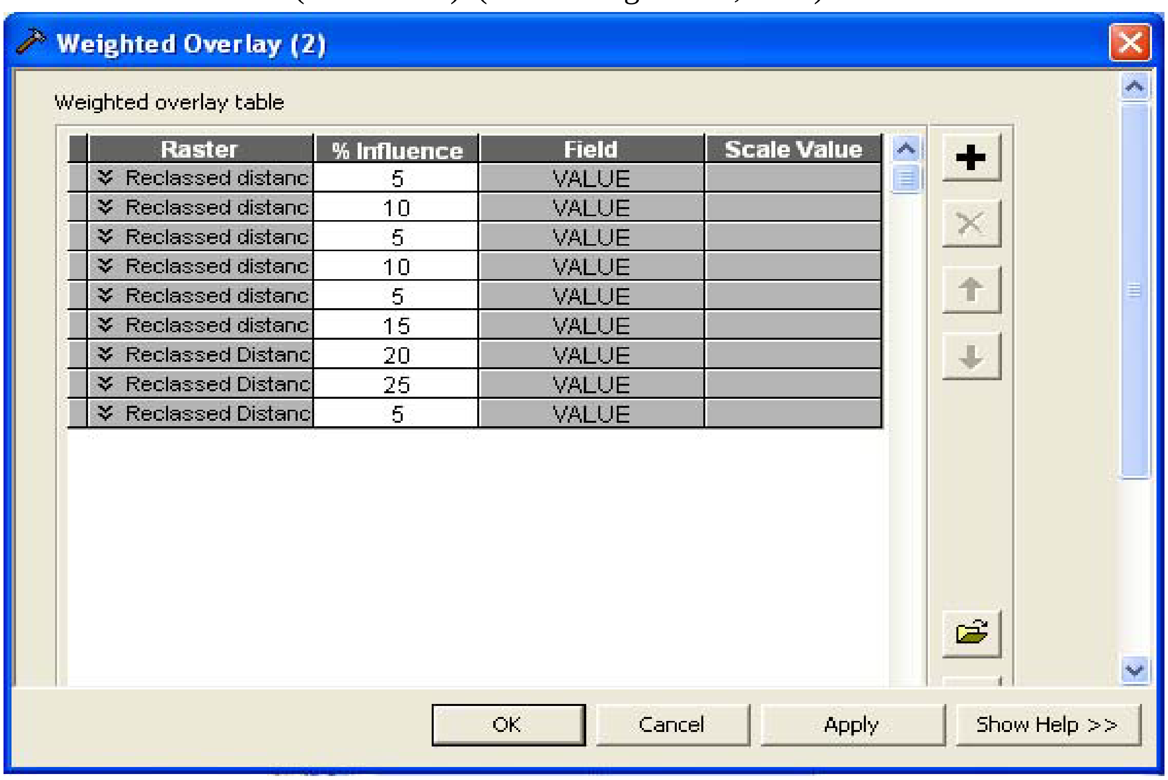
6.3 Weighting:

There are varieties of parameters and variables considered in the routing of the pipeline process, therefore, it is essential to rank or weight each one of those variables in order of significance. This operation aim in determining the magnitude of contribution each parameter has on the site selection process. In order to fulfill this task, efforts have been made to ensure the involvement of the society in regions where the route. A questionnaire was accomplished, in order to achieve the participants sought and views. Since they will be directly affected if the pipe failures take place in the future (Balogun et al, 2012).

Each parameter is coded on scale of 1 to 100 based on the:

- Their vulnerability to environmental degradation,
- Cost and total contribution on the selected route.

Fig. 16: below shows the assigning rank to the routing criteria in order of contributions (%influence). (After Balogun et al, 2012)



6.4 Results and Discussions:

The best or optimal route is produced from the cost ranked (weighted) raster below

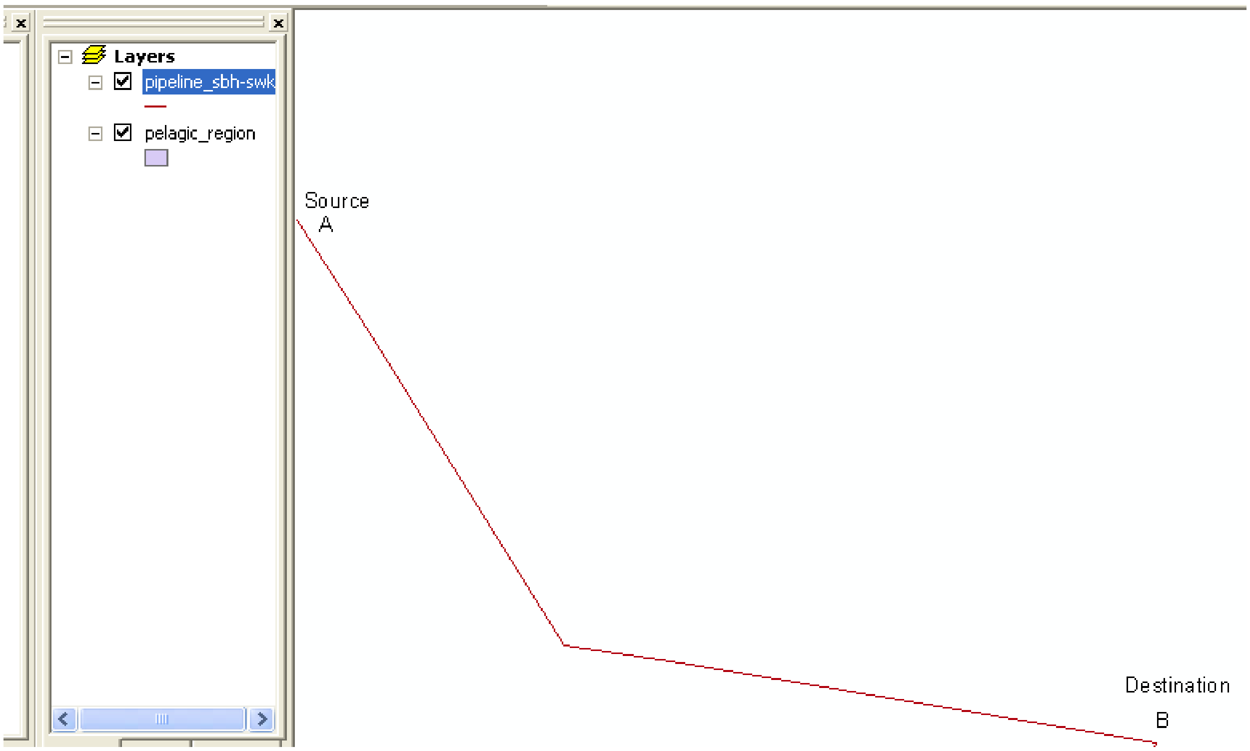


Fig. 17: The optimal route for the pipeline from the oil field (A) to final destination (B) (after Balogun et al, 2012)

In order to transfer the crude oil from the source (A) to its target (B) there was several possible routes through which the pipeline could pass. Consequently, depending on the assigned weight and the routing criteria, the optimal possible is generated as illustrated in the previous figure. Through this route all the following could be minimized;

- Public health hazards,
- Environmental degradation,
- And destruction of ecosystem

Moreover if this route is adopted the construction and maintenance costs when operational would be lower.

7. Conclusion:

Capability of integration and comparison of various datasets using GIS enable the geoscientists to get maximum possible information from the study area. That information, for example, includes fault fractures, HSE issues, topographic surface and dip and strike structures. And consequently, applies them to design the operations step before on-site operation. Hence, what so called exploration process, has increased the assurance of the survey to be performed and effectiveness of time and cost savings.

Ethiopia project demonstrate that the exploration workflow by using the GIS in operation of designing seismic survey with the incorporation of geophysical, geological and other type of data improve the operations in terms of data quality, costs, time and accuracy. This approach is accomplished by gathering, registering, and analyzing the data achieved from different methods in GIS for part block PCOSB in Ethiopia.

In the exploitation part of the petroleum industry resembled by site selection of the pipeline, the GIS technology has been successfully deployed. By integrating sought of the concerned members of the local society in ranking of the variables, consequently a reliable and optimal pipeline route had been generated.

This approach implies that the GIS technology can be consider by far an effective tool that enables multi-disciplinary teams in the petroleum exploration and exploitation phases to share the information, analyzing the data in new ways and incorporate the evaluation processes. This approach can indeed enhance at the end of the day the overall problem-resolving operation.

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