CHAPTER (3)

RANKING AND OPTIMUM DATA SELECTION PATH

3.1 INTRODUCTION

In this thesis, data is extracted from the analysis of 20 cases that are carefully selected from about 100 projects and scientific papers that support the use of remotely sensed data for oil exploration. The target from such selected cases is to develop an initial guide for oil and gas expertise supporting decision making for using the most suitable satellites and other data sets that suits the conditions of the concession area. Also the different categories i.e. (sea/ocean-Desert- grasslands.etc.) and types of study areas increased the opportunity to offer a complete solution if exploration companies decided to use satellite for finding oil indicators.

Differences between using satellite images in seismic and non seismic surveys are also includes in this study with the value of using multi temporal and/or multi source satellite images. Finally, the main factors that may increase or decrease the probability of oil existence will be extracted and evaluated, by giving a rank for every factor and the relation between different factors will be discussed later.

3.2 DATA STUDY FOR SELECTED CASES

This section includes a summery for the selected cases explaining some important information about study area and the used satellite image, interpretation methods …etc.

3.2.1 Case 1:

Summary: Combining Bands 4, 3 and 2 of the LISS-III image, a false color composite (FCC) was generated. Spatial enhancement was also done to the IRS 1-D PAN and LISS-III images. To take advantage of the spatial resolution and spectral resolution of the IRS 1-D PAN and LISS III images, respectively, both images were "resolution merged" together to obtain a multi-spectral image having higher spatial resolution. A modified geological atlas was generated based on interpretations from the multi-spectral image having higher spatial resolution, following image radiometric enhancements. The topographic contours and elevation points were interpolated using the Triangulated Irregular Network (TIN) method to generate the Digital Elevation Model (DEM), slope map and aspect map of the study area. In order to generate Digital Terrain Models (DTMs), the LISS-III, PAN and merged images were draped over the DEM. DTM generated by combining the LISS-III image with the DEM (Mishra et al, 2003).

Table 3.1: Case 1 data summary

Reference/Magazine	Map India Conference 2003
Operator	Hindustan Oil Exploration Company Limited
Authors	Premanand Mishra and Sagar N. Mehta
Date	2003
Type	Seismic Survey
Study area	Assam-Arakan fold-thrust belt (FTB) –India
Topography	Desert-Rugged terrain
Satellites	IRS-1D LISS-III and IRS-ID PAN.
Bands	4, 3 and 2 of the LISS-III image
Data Used	1. Remote sensing digital data of IRS-1D LISS-III and IRS-ID PAN. 2. Existing geological maps, structure contour maps, and topographical maps (1:50,000 scale). 3. Field survey data of existing well and seismic line locations, as well as GPS survey points (used as GCPs during geo-referencing).

3.2.2 Case 2:

Summary: In this study (case2) the challenge was to combine different interpretation methods to pick up more rich reliable and useful information through the process of merging multi-source and multi-temporal remote sensing data through the information fusion of remote sensing imagery. Tonal anomalies and subtle change in information content are used as important indicators when applying imagery for oil and gas exploration. The utilized interpretation methods: (Contrast enhancement - Band ratio - Principal composite analysis - Color spatial transform) (Wuyi et al, 2003).

Table 3.2: Case 2 data summary

Reference/Magazine	22nd Asian conference on remote sensing 2001
Operator	Research institute of petroleum exploration and development of petro china co Ltd , Beijing
Authors	Yu Wuyi , Qi Xiaoping , ZouLiqun
Date	2001
Type	Non-Seismic Survey
Study area	Loess Highlands , Ordos Plateau, China
Topography	Desert with Sparse vegetation
Satellites	Multi source , Multi Temporal satellites
Bands	B1, B3, B5 from TM 128'34 (sept.87) – B2 and B7 from TM 128'34 (Jan. 98) – B4 from ETM (April and May 2000)
Data Used	Multi - temporal and Multi - source satellite images

3.2.3 Case 3:

Summary: This case have been made SST processing by NOAA-11 CH 4,5 band , false color image processing CH5,2,1 , and more factor correlation analysis between gray value and thermal current value (Ruisong, 2001)

Table 3.3: Case 3 data summary

Reference/Magazine	petroleum and gas research by remote sensing
Operator	Guangzhou institute of geochemistry, Chinese academy of science
Authors	prof. Xu Ruisong
Date	2001
Type	Non-Seismic Survey
Study area	South China Sea
Topography	Sea
Satellites	NOAA-11
Bands	CH 1,2,4,5
Data Used	Multi - Temporal Satellite images (The remote sensing data are from NOAA-11 1990 – 1993 – 1994)

3.2.4 Case 4:

Summary: Band 5 was chosen for maximum contrast throughout the image. Band 7 was chosen because it provides the best penetration of atmospheric haze and delineates water bodies better than any other single band. The false color composite was chosen because it allows better differentiation between cover types than any of the four bands separately. The false color composite is created by combining bands 4, 5, and 7. Each of the three bands are exposed on photographic transparency material, generating the master transparency. The linear features were mapped from the band 5 and band 7 prints. As with the drainage channels with geological structures (RICKY et al,1982)

Table 3.4: Case 4 data summary

Reference/Magazine	Use of remote sensing techniques and statistics in petroleum exploration : permain basin , Texas
Operator	Faculty of Texas Tech University
Authors	RICKY G. COX, B.S
Date	1982
Type	Seismic Survey
Study area	PERMIAN BASIN- Texas
Topography	Desert
Satellites	Landsat-2
Bands	4,5,7
Data Used	Satellite image – geological data – seismic cross sections

3.2.5 Case 5:

Summary: The geologic interpretation of satellite image focused on the interpretation of fractures and structures that may indicate fracture reservoir conditions and any tonal or vegetation anomalies that may indicate the seepage of hydrocarbon.

Table 3.5: Case 5 data summary

Reference/Magazine	Remote sensing and fracture analysis for petroleum exploration of Ordovician to Devonian fractured reservoirs in new York state
Operator	New York State Energy research and Development Authority
Authors	Earth Satellite Corporation.
Date	1997
Type	Non-Seismic Survey
Study area	New York portion of the Appalachian basin
Topography	Desert
Satellites	Landsat Thematic Mapper (10 scenes)
Bands	7,4,2
Data Used	Satellite image – geological data

Spatial resolution was 28.5 meters in six visible (VIS), near infrared, and short wave infrared (SWIR) bands – spatial resolution 120 meters in the thermal infrared (TIR) band (ESC,1997)

3.2.6 Case 6:

Summary: This study will focus on visual observations and interpretations, using special software to enhance and compare the seismic profile fault zones and folds that are not indicated in already existed geological and structural maps. GIS will be applied to explore advanced visualizations techniques made available with ArcGIS techniques. This will allow to predict petroleum system evolution of Ghadamis Basin (BENISSA, 2006).

Table 3.6: Case 6 data summary

Reference/Magazine	Application of remote sensing and GIS for petroleum exploration in GHADAMIS basin, NW Libya
Operator	Libyan Petroleum Institute
Authors	MAHMOUD ALI BENISSA
Date	2006
Type	Seismic Survey
Study area	GHADAMIS basin, NW Libya
Topography	Desert
Satellites	SPOT images
Bands	Not recorded
Data Used	Satellite image – geological data – seismic cross sections – GIS data

3.2.7 Case 7:

Summary: Landsat images and a digital elevation model covering the central and southern portions of the Masilah Basin in the Republic of Yemen have been used to enhance the mapping of poorly imaged structural features. An absence of recent post-rift sediments within the study area allowed Mesozoic and Cenozoic extensional features to be mapped on the surface from satellite data and then extrapolated to analogous subsurface structures identified on a 2D seismic grid. Combining bands 7 (reflected infrared (IR)), 4 (reflected IR) and 1 (blue-green) as a RGB raster in

ERMAPPER produces an image which gives the best distinction of outcropping formations in Eastern Yemen (Harris et al, 2002).

Table 3.7: Case 7 data summary

Reference/Magazine	Focusing Oil and Gas Exploration in Eastern Yemen by Using Satellite Images and Elevation Data alongside Conventional 2D Seismic
Operator	EnCana Corporation, Calgary, Canada
Authors	Richard Harris, Mark Cooper, Ian Shook
Date	2002
Type	Seismic Survey
Study area	Masilah Basin
Topography	Desert
Satellites	Landsat 7
Bands	7,4,1
Data Used	Satellite image – geological data – seismic cross sections – DEM

3.2. 8 Case 8:

In this case, a general review of all the spectral regions in which remote sensing for the detection of oil in oceans is carried out along with their advantages and disadvantages had been discussed.

Summary: The detection of oil seepage in oceans is of foremost importance from the exploration point of view since they are the primary manifestations of any sort of oil accumulation beneath the ocean bottom and offer clues as to where oil deposits may be located in ocean basin, 80% of offshore oil exploration starts by searching for seeps. Work published by BP and others in the early 90's (NPA, 2004) demonstrated that over 75% of the world's petroliferous basins contain surface seeps (Mazumder et al , 2006).

Table 3.8: Case 8 data summary

Reference/Magazine	6th International Conference & Exposition on Petroleum Geophysics "Kolkata 2006"
Operator	Remote Sensing &GeomaticsDiv, KDMIPE Oil and Natural Gas Corporation Limited
Authors	Subhobroto Mazumder and Kalyan Kumar Saha
Date	2006
Type	Non-Seismic Survey
Study area	Gulf of Mexico
Topography	Ocean
Satellites	SAR(microwave spectral region) - LANDSAT TM(visible regions, bands 1-3) - laser fluorosensors used for oil slick detection uses a laser operating in the range between 0.3 to 0.355 μm (ultraviolet region)
Bands	Not recorded
Data Used	satellite images

3.2.9 Case 9:

Summary: RADARSAT-1 images were used as an attempt to identify seepage slicks in the Foz do Amazonas Basin, a region that is cloud-covered for most of the year. An unsupervised semivariogram textural classifier algorithm was used to enhance areas of smooth texture and low radar backscatter, indicative of these seepage slick targets.

Table 3.9: Case 9 data summary

Reference/Magazine	RADARSAT-1 images in support of petroleum exploration: the offshore Amazon River mouth example
Operator	EnCana Corporation, Calgary, Canada
Authors	R. Almeida-Filho, F.P. Miranda, J.A. Lorenzzetti, E.C. Pedroso, C.H. Beisl, L. Landau,M.C. Baptista, and E.G. Camargo
Date	2005
Type	Seismic Survey
Study area	Foz do Amazonas Basin, Brazil
Topography	River
Satellites	RADARSAT-1
Bands	C-band
Data Used	Satellite image – geological data – seismic cross sections

Complementary information related to sea surface temperature, cloud top temperature, wind velocity, and modeling for the tidal regime was used to support image interpretation and to exclude false targets also characterized by low radar backscatter (Filho et al, 2005).

3.2.10 Case 10:

Summary: The capacity of satellite imagery to detect anthropogenic impacts on land cover was assessed for the Bovanenkovo gas field on the Yamal Peninsula in northwest Siberia, which contains some of the world's largest untapped gas deposits.Very-high-resolution Quickbird-2 imagery revealed the most impacts, but could not detect items like trash that reduce the quality of reindeer pastures. ASTER, SPOT, and Landsat imagery were useful at the broader landscape level (KUMPULA et al, 2009)

Table 3.10: Case 10 data summary

Reference/Magazine	Remote Sensing and Local Knowledge of Hydrocarbon Exploitation: The Case of Bovanenkovo, Yamal Peninsula, West Siberia, Russia
Operator	The Arctic Institute of North America
Authors	T. KUMPULA,1 B.C. FORBES2 and F. STAMMLER3
Date	2009
Type	Seismic Survey
Study area	Bovanenkovo gas field- Siberia
Topography	Desert
Satellites	Quickbird-2- ASTER, SPOT
Bands	Not recorded
Data Used	Multi source satellite images

3.2.11 Case 11:

Summary: Non-seismic geophysical exploration techniques are important strategic components of the exploration tool kit when properly calibrated and applied. non-seismic exploration technologies including gravity was reviewed, magnetic, marine electromagnetic, airborne EM, magnetotellurics, remote sensing, Light touch, and others, indicate recent advances and developments that have enhanced their value, and present real examples and case histories that illustrate the benefits in using combinations of these tools for large scale exploration activities (Biegert, 2007).

Table 3.11: Case 11 data summary

Reference/Magazine	From Black Magic to Swarms: Hydrocarbon Exploration using Non-Seismic Technologies
Operator	Shell International Exploration and Production
Authors	Ed. K. Biegert
Date	2007
Type	Non-Seismic Survey
Study area	Gradient field.
Topography	Desert
Satellites	radar imagery
Bands	Not Recorded
Data Used	gravity, magnetics, marine electromagnetics, airborne EM, magnetotellurics, remote sensing, LightTouch data

3.2.12 Case 12:

Summary: Two images acquired, merged and georectified to provide coverage beyond bounds of reservation area - National Elevation Dataset (NED) windowed and combined with Landsat ETM7+ imagery to provide elevation control - Bands 3, 4, 5 interpreted with and without elevation data - Interpretation directed towards fault influence of surface geomorphology(ARIH)

Table 3.12: Case 12 data summary

Reference/Magazine	Identifying Oil Exploration Leads Using Integrated Remote Sensing and Seismic Data Analysis, Lake Sakakawea, Fort Berthold Indian Reservation,Williston Basin
Operator	Advanced Resources International Houston, TX with Bureau of Indian Affairs Lakewood, CO
Authors	not recorded
Date	2009
Type	Seismic Survey
Study area	Williston Basin-India
Topography	Desert
Satellites	LandSat ETM7
Bands	3, 4, 5
Data Used	seismic data – geological maps – satellite images

3.2.13 Case 13:

Summary: The 2013 Indonesia licensing round is offering approximately 100,000 km^2 of offshore acreage. These blocks have already been covered by NPA's Global Offshore Seepage Database (GOSD). Seepage detection by SAR (Synthetic Aperture Radar) is a proven technique for mapping surface oil seeps which could provide the first indication of petroleum systems in these blocks.(GOSD, 2013)

Table 3.13: Case 13 data summary

Reference/Magazine	Indonesia 2013 Seepage Study
Operator	Global Offshore Seeps Database
Authors	not recorded
Date	2013
Type	non-Seismic Survey
Study area	Indonesia
Topography	Desert
Satellites	SAR scenes - TerraSAR-X, Radarsat-2
Bands	Not Recorded
Data Used	satellite images

3.2.14 Case 14:

Summary: Numerous oil slicks of natural origin were revealed in the southwest part (SW) of Caspian Sea on the synthetic aperture radar (SAR) images acquired by the Envisat satellite in 2003-2004. Analysis of the SAR images together with bathymetry, geophysical and seismic data in geographic information system showed that the main hydrocarbon contribution visible on the sea surface as oil slicks comes from the natural seepage (Victoria et al, 2007)

Table 3.14: Case 14 data summary

Reference/Magazine	Application of ENVISAT SAR imagery for mapping and estimation of natural oil seepage in the south Caspian sea
Operator	Envisat Symposium 2007', Montreux, Switzerland
Authors	Victoria V. Zatyagalova, Andrei Yu. Ivanov, Boris N. Golubov
Date	2007
Type	Seismic Survey
Study area	Caspian sea
Topography	Sea
Satellites	Multi-Temporal ENVISAT images
Bands	Not Recorded
Data Used	satellite images seismic data – bathometry maps

3.2.15 Case 15:

Summary: The presence of seepages documents the first element of a hydrocarbon system and could therefore reduce exploration risks. Hydrocarbons that escape from underground reservoirs cause oxidation-reduction reactions either in situ or along vertical migration pathways and result in anomalies in the surface sediments and soils. The surface changes can be detected by multispectral remote sensing. The spectroscopy and ASTER multispectral remote sensing were employed to investigate hydrocarbon seepage-induced anomalies in the Kuqa depression basin, southern Tian Shan Mountain, west China, combined with field investigations, geochemical and mineral analyses of selected samples (Shi et al, 2010).

Table 3.15: Case 15 data summary

Reference/Magazine	Mapping hydrocarbon seepage induced anomalies in the arid region, west china using multispectral remote sensing
Operator	Institute of Geology and Geophysics, Chinese Academy of Sciences,Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology
Authors	Pilong Shi, Bihong Fu, YoshikiNinomiyab
Date	2010
Type	Non - Seismic Survey
Study area	Kuqa depression basin
Topography	Desert
Satellites	ASTER multispectral
Bands	Not Recorded
Data Used	satellite images – geological data

3.2.16 Case 16:

Summary: Based on the hydrocarbon microseepage theory, the analysis of crude oil in soil in Qaidam Basin and spectral experiment of crude oil in sea water in Liaodong Bay, Hyperion hyperspectral remote sensing images were used to develop the method of oil-gas exploration (Tian, 2012).

Table 3.16: Case 16 data summary

Reference/Magazine	study on Oil-Gas reservoir detecting methods using hyperspectral remote sensing
Operator	International Institute for Earth System Science, Nanjing University
Authors	Qingjiu Tian
Date	2012
Type	Non - Seismic Survey
Study area	Qaidam Basin and Liaodong Bay - China
Topography	Desert
Satellites	Hyperion hyperspectral remote sensing images
Bands	Not Recorded
Data Used	satellite images – geological data

3.2.17 Case 17:

Summary: Predicting and mapping rock and soil alteration from satellite imagery is an accepted practice for mineral exploration, where heat and chemical changes from intrusions alter country rocks in phases that can be spectrally characterized and associated with ore. Geochemical alteration is noted in rocks associated with hydrocarbon micro seepage and changing pH, but relatively few investigations document this approach. It is proposed that hydrocarbon migration has altered surface rocks in Kurdistan as evidenced by digital image analysis of Landsat and ASTER satellite imagery. Spectral measurements of hand samples collected within suspect terrain show strong indicators of alteration mineralogy from exposed upper and lower Fars Formation. While still preliminary, the mineral jarosite appears ubiquitous in hand samples tested so far suggesting acidic, sulfate-rich surface conditions not normally associated with lithology of the region.(Sandra et al, 2011)

Table 3.17: Case 17 data summary

Reference/Magazine	Evidence of Hydrocarbon Seepage Using Multispectral Satellite Imagery, Kurdistan, Iraq
Operator	Horizon GeoImaging LLC, Frisco, CO
Authors	Sandra L. Perry and Fred A. Kruse
Date	2011
Type	Non - Seismic Survey
Study area	Kurdistan- Iraq
Topography	Desert
Satellites	Landsat Enhanced Thematic Mapper (ETM) and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) multispectral bands
Bands	Landsat visible and near-IR (VNIR) bands 1, 2, and 3 were combined with ASTER short-wave IR (SWIR) bands 5, 6, 7, 8, and 9
Data Used	satellite images – geological data

3.2.18 Case 18:

Summary: Highly accurate stereo satellite elevation maps are being used in many phases of oil and gas exploration and development throughout the world. The benefits of the stereo satellite elevation mapping include surficial and bedrock geologic mapping, improving the safety and the quality of onshore 3D seismic surveys, and planning and construction of onshore oil fields and the coastal facilities for offshore developments. Pipeline routes and oil and gas facilities are being planned and constructed using stereo satellite elevation mapping for horizontal and vertical control.(Mitchell, 2011).

Table 3.18: Case 18 data summary

Reference/Magazine	The Application of Highly Accurate Stereo Satellite Elevation Mapping to Oil and Gas Exploration and Development
Operator	PhotoSat
Authors	Gerry Mitchell
Date	2011
Type	Seismic Survey
Study area	Ghadames Libya
Topography	Desert
Satellites	WorldView -2 - GeoEye
Bands	Not recorded
Data Used	satellite images – geological data - seismic data - DEMs

3.2.19 Case 19:

Summary: Radar images of the southwestern part of the Caspian Sea received from Envisat satellite in 2003-2004 revealed a large number of oil slicks of natural origin. Computer processing and visual interpretation of the radar images as well as comparison with offshore geological-geophysical and seismic survey data and utilization of geo information system relate these slicks to underground fluid discharge (oil, gas, formation water) in the south Caspian tectonic depression. Impact of the oil discharge on the Caspian ecological situation is herein proved to be significant (Ivanov et al, 2006).

Table 3.19: Case 19 data summary

Reference/Magazine	Oil and Gas Seeps and Underground Fluid Discharge in the Southern Caspian Based on Space Radar Data
Operator	Shirshov Institute of Oceanology, Russian Academy of Science, Moscow Institute of Geospheres Dynamics, Russian Academy of Science, Moscow Almaz Center, Federal State Unitary Enterprise "NPO Mashinostroyenia", Reutov, Moscow Region
Authors	A. Yu. Ivanov, B. N. Golubov, B. B. Zatyagalova3
Date	2006
Type	Seismic Survey
Study area	Caspian Sea
Topography	Sea
Satellites	Multi-Temporal ENVISAT images
Bands	Not recorded
Data Used	satellite images – geological data – Siesmic Survey

3.2.20 Case 20:

Summary: Seven AVIRIS images of Santa Barbara, CA, were classified in this project using two standard spectral matching techniques: SAM and SFF. Four of the seven images had previously mapped seep locations. The minerals alunite, calcite,jarosite, kaolinite, and siderite were mapped, as well as two vegetation classes. For this study, jarosite was found to have the most potential as a hydrocarbon indicator because it was rarely classified and classified pixels often corresponded to where hydrocarbon seeps had been mapped. (Freeman, 2003)

Table 3.20: Case 20 data summary

Reference/Magazine	Evaluation of the use of hyperspectral imagery for identification of micro seeps near Santa Barbara, California
Operator	West Virginia University
Authors	Heather Freeman
Date	2003
Type	non - Seismic Survey
Study area	coastline near Santa Barbara
Topography	Sea
Satellites	Multi temporal AVIRIS
Bands	Not recorded
Data Used	satellite images – geological data

3.3 Objects Library for Oil Existence Indicators Interpreted On Different Satellites

This section explains the common indicators seen in satellite images of all cases, this includes the display of the used satellite image focusing on the objects that was identified as Oil existence indicator.

3.3.1 Detection of Oil Indicators in Ocean / Sea Area

In the offshore, seeping oil and gas are often easier to detect due to the fact that oil is normally transported from the sea-bed vent to the surface as oil-coated gas bubbles. At the surface, the gas bubble bursts and the oil remains on the surface as a thin oil film as shown in Fig (3.1) a.

Figure 3.1a: Surfacing oil pancakes (gas bubbles burst and lost to atmosphere) .(Mazumder et al, 2006)

Figure 3.1b: Coalescing oil pancakes forming large oil seepage slick (aerial view).(Mazumder and saha, 2006)

In calm sea conditions, these can often be viewed as beautiful, iridescent concentric shapes, typically 0.5 to 1 meter in diameter, known as 'oil pancakes'. As seepage continues over time, these coalesce to form larger slicks that are detectable from aircraft Fig (3.1) b.

3.3.1.1 Detection of Oil in Various Spectrums

Different spectrum areas have different reflectance with objects that indicates the existence of oil and, below a summery for the detection of oil in various spectrum.

3.3.1.1.1 Detection in the Thermal Infrared Region

The oil is found to show a number of thermal properties that distinguish it from water. These include thermal capacity, thermal conductivity and thermal inertia.

This method has been used for the detection of oil spills only but it has its own disadvantages. Often cool water currents of oceans present a similar image as oil spills. This problem can be minimized using information from the ultraviolet spectral ranges along with that of the thermal information. Clouds also act as a barrier to thermal sensing, as they are good absorbers of the thermal radiation.

3. 3.1.1.2 Detection in the Ultraviolet Region

Ultraviolet images can be used to map films of oil (as thin as 0.15 μm) firstly due to their high reflectivity and secondly since in this region the difference in the spectral response of oil and water is the maximum here. Also, it is found that in the presence of solar radiation, many oils show the phenomenon of fluorescence in the ultraviolet part of the spectra.

However, this type of detection systems has their own disadvantages. One is that, this is dependent entirely on the sun as its source of radiation and hence can work only during daytime and that also in a clear weather. Another disadvantage is that, there is a great deal of selective scattering by the atmosphere as the ultraviolet rays travel back from the target to the sensor and this in turn causes a very low contrast in the signal. However, the effect of scattering is found to be much less for images that are acquired at an altitude of 1000 m or less and hence a low flying aircraft is used in this case rather than any space based platform. To overcome the shortcomings of the passive ultraviolet system, active ultraviolet systems are being used (Williams, 2002).

3.3.1.1.3 Detection in the Visible Region

The visible region does not provide too much of a contrast between water and oil and it needs thorough processing to yield better results. The effect of wind causes surface waves in ocean which causes the surface of oil to show a high reflectance than the surrounding water in moderate to high elevation, this makes it possible to some extent to detect the oil seepages in ocean water.

3.3.1.1.4 Oil Spill Detection in the Microwave Region

Since 1992, a powerful and cost-effective platform for offshore seepage detection has emerged. This is satellite borne active microwave radar or SAR (Synthetic Aperture Radar). This is due to their ability to image surface oil seeps remotely with wide swath coverage (typically 100 x 100 kms scenes for ERS and 165 x 165 kms for Radarsat Wide 1) and at low cost. Moreover, satellite data is free skies and is being continuously acquired, thus providing multi-temporal satellite data over any area of the globe. Such repeat seeps provide the location for follow-up surface sampling from which key geochemical information on the reservoir oil can be obtained ahead of the drill.

SAR satellites scan the oceans continuously on fixed polar orbits. They have advantages over optical satellite systems, such as Landsat TM and airborne systems in that they observe night and day and penetrate cloud cover. SAR creates images of the sea surface detailing its morphology. Radar images map slicks (flat patches of the surface) that can be related by analysis to petroleum seepage.

3.3.2 Offshore Seeps- Detection by SAR Technology

In offshore Basins, oil seeps from reservoir can reach the sea surface, usually in the form of oil coated gas bubbles, and then form slicks identifiable from satellite.

This is due to the dampening effect of the oil on the capillary wavelets, which produces an area of relative calm compared to the background waves. The satellite data to be chosen should be screened for weather, mainly for wind speed, as this parameter has a direct implication on slicks (Srivastava, 2005).

Slicks are interpreted on the SAR imagery as dark patches. The pollution slicks are thicker than the seepage slicks. The seepage slicks are ultra thin films. They do repeat in time, but often not observed and they often form in clusters because seepage vents are never singular as shown in Fig (3.2)

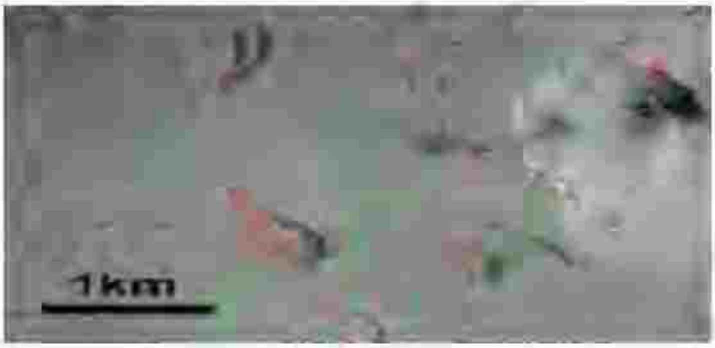


Figure 3.2: Seepage Slicks repeating in time in Gulf of Mexico (NPA, 2004).

The colored polygons Fig (3.2) outline slicks mapped on satellite radar acquired on dates different from the image shown. The region shown has been sampled four times over a three-year span (NPA, 2004).

Satellite SAR systems are very effective at observing slicks, both man- made and natural, but very few slicks result from hydrocarbon seepage-very rarely more than 5% of the total number of slicks detected (NPA, 2004).

Only these seepage slicks are of exploration interest. A consistent and systematic analysis scheme to discriminate seepage slicks from other slicks has been developed. Three main categories of slicks are distinguished: seepage slicks, pollution slicks, and natural film slicks. Natural film slicks are formed from an ultrathin layer of long-chain organic molecules-derived largely from decayed plankton-and appear on low wind speed images (Williams, 2002).

Some of the parameters used to categorize and discriminate seepage slicks are:

Size: The minimum resolvable seepage slick is ~100–150 m long, dependent on sea state and sensor. Slicks are smaller than this will not be resolved by SAR.

Direction of flows (streaming direction): Seepage slicks will conform to dominant wind and current directions (and/or tidal effects). Fresh pollution slicks, especially from ships, are typically straight and have a distinct feather edge where older material is blown by wind.

Context: This is either geologic (i.e., location over plausible migration conduits) or geographic (i.e., location within shipping lanes or in areas of oil production).

Backscatter reduction: Oil slicks (seeps and pollution) generally have a greater contrast and edge enhancement (i.e. Sharpness) than natural films have, but this property is dependent on wind speed.

Edge characteristics (i.e., sharpness) and relation to wave facets, current, and wind: These details are critical to the analysis because they depend on the slick thickness and material.

Repetition: A repeating emission point is shown on successive images. This is the most compelling parameter but is restricted to the leakiest basin types (episodic seepage is a feature of most seepage and in most offshore basins).

Ocean features: These features have to be analyzed and accounted for in the slick analysis. The confidence with which a slick can be categorized on weather-compliant images is derived from considering all the above parameters. Seepage slicks are ranked 1, 2, or 3, based on these confidence limits Fig (3.3) a, b, c.

(a) Rank 1: nested multiple source slicks. Image is 30 km across.

(b) Example of Rank 2 (remnant) pollution slick. (Fragmented pollution from ship, six days after discharge).

(c) Rank 3: small cluster slicks are ~ 120m long (NPA Group, 2004).

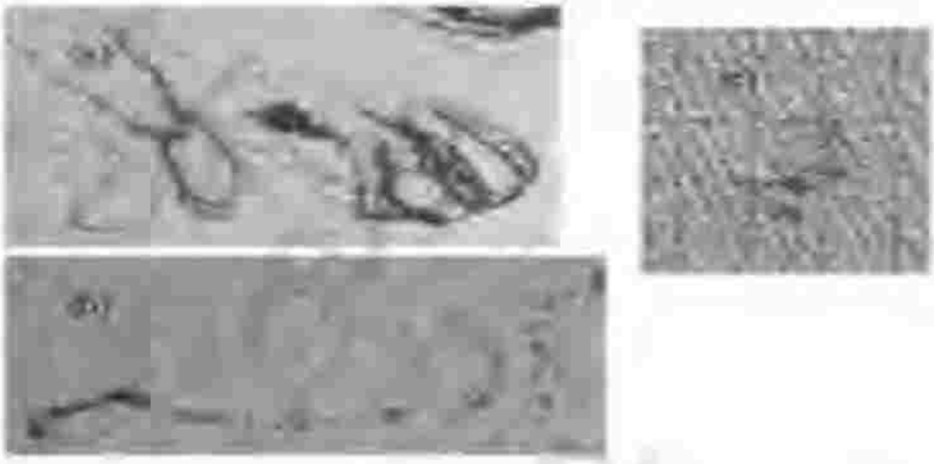


Figure 3.3. Seepage slicks ranking (Mazumder and saha, 2006)

Seepages and oil spills, provides size estimates, and help predict the movement of the slicks and possibly the nature of the oil. Though the entire electromagnetic spectrum beginning from the ultraviolet can be utilized in remote sensing of oil, the best results are obtained in the ultraviolet, thermal and microwave regions of the spectrum. Of these, the active microwave sensors come near to the description of an ideal remote sensing system with large ground coverage, round the clock operations under all weather conditions, cost effective and are useful for detection of both oil seepages and oil spills. These technology can offer the oil industry an effective, low-cost technique for reducing risk in high cost exploration environment (Mazumder et al, 2006).

3.3.3 Detection of oil indicators in the offshore River

As a result of the USTC algorithm application, several regions with smooth texture were identified in the RADARSAT-1 images. After elimination of false targets by using the ancillary oceanographic and meteorological information, distinctive elongated features were interpreted as associated with seepage slicks.

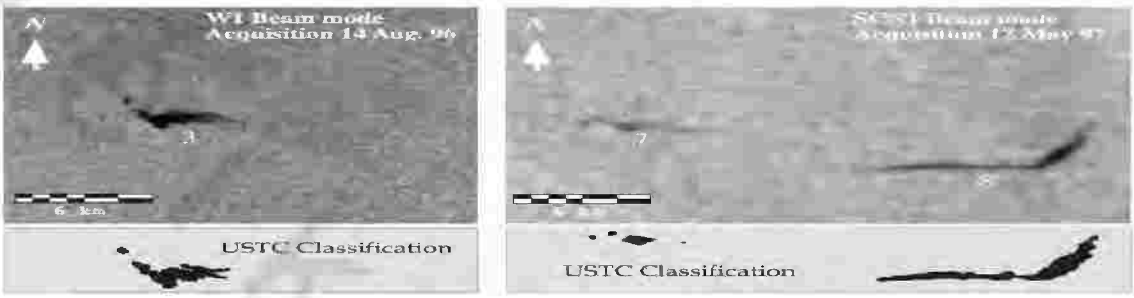


Figure 3.4. Examples of seepage slicks identified on RADARSAT-1 SCN1 and W1 images and corresponding USTC classification results.

*Numbers refer to seepage slick identification numbers.

3.3.4 Detection of Oil Indicators in Desert Area

A proper assessment of the overall ecological impacts of hydrocarbon exploitation requires a combination of remote sensing and detailed ground-truthing. Ideally, these efforts should combine scientific and local knowledge from both indigenous herders and non-indigenous industrial workers.

Impacts associated with exploration and production activities are exposed. These range from physical obstructions, such as roads, railways, and pipelines, to direct and indirect ecological impacts, such as changes in vegetation and hydrology. Nenets' perceptions of their territories encompass changes in the quantity and quality of terrestrial and freshwater habitats and campsites that have been used seasonally for centuries. Industrial impacts on land cover were examined at spatial scales from very detailed to coarse. Very-high-resolution Quickbird-2 imagery revealed the most impacts, but could not detect items like trash that reduce the quality of reindeer pastures. ASTER, SPOT, and Landsat imagery are useful at the broader landscape level.

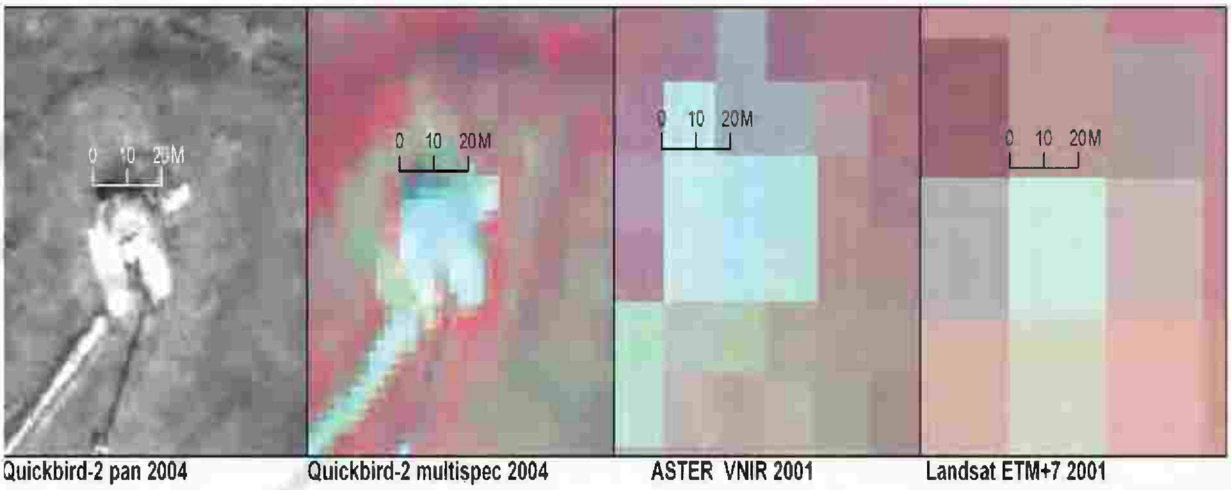


Figure 3.5: Detecting small- and medium-scale impacts. With Quickbird-2 panchromatic imagery(KUMPULA, 2009)

The capacity for different satellite platforms to detect impacts at three scales was investigated, small (less than 0.09 ha), medium (0.1 ha to 1 ha), and large (more than 1 ha) (Table 1, section 2.5.5.1). Usually, large scale extends up to 2000 km^2.

The size and the nature of most surface disturbances can be reliably determined. In multispectral Quickbird-2 imagery, details are detectable but more blurry. In ASTER imagery, the size, shape and nature of objects are somewhat unclear, and with Landsat ETM+7 imagery, the impact is barely observable.

The capacity to detect single and multiple off-road vehicle tracks as shown in Fig (3.6) when individual vehicle tracks are multiplied and spread out, they appear as medium-scale impacts and are therefore possible to detect from coarser imagery (KUMPULA, 2009).

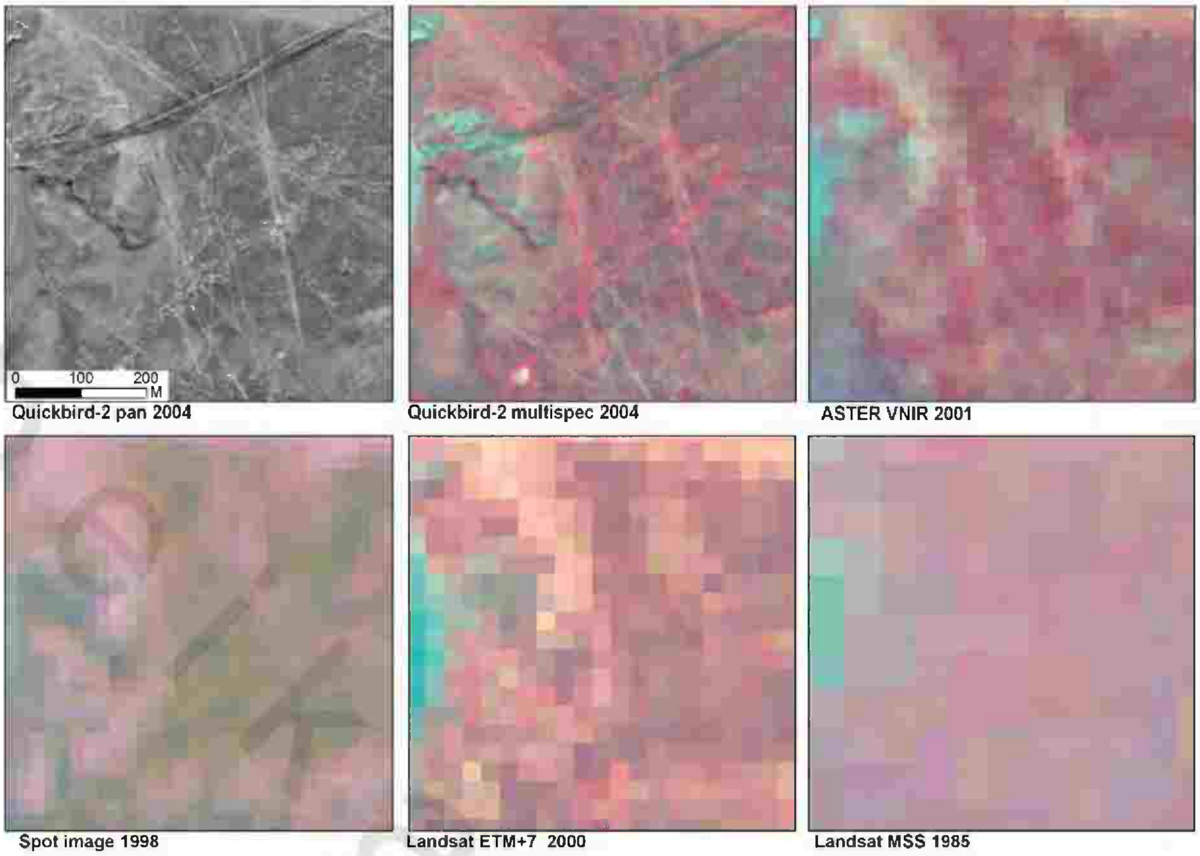


Figure 3.6: Small - and medium -scale impacts.(GOSD, 2013)

Comprehensive mapping and categorization of offshore oil seeps is essential for efficient offshore oil and gas exploration. Enhanced and interpreted SAR satellite imagery is capable of identifying key regions of seepage as shown in, Fig (3.7) and (3.8)thus focusing exploration efforts and reducing costs (GOSD, 2013).

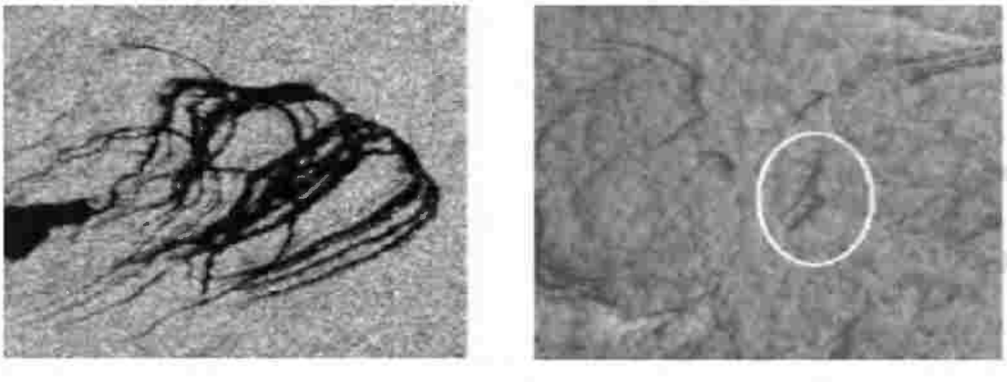


Figure 3.7: Direct detection of hydrocarbon seeps using radar imagery (Biegert, 2007).

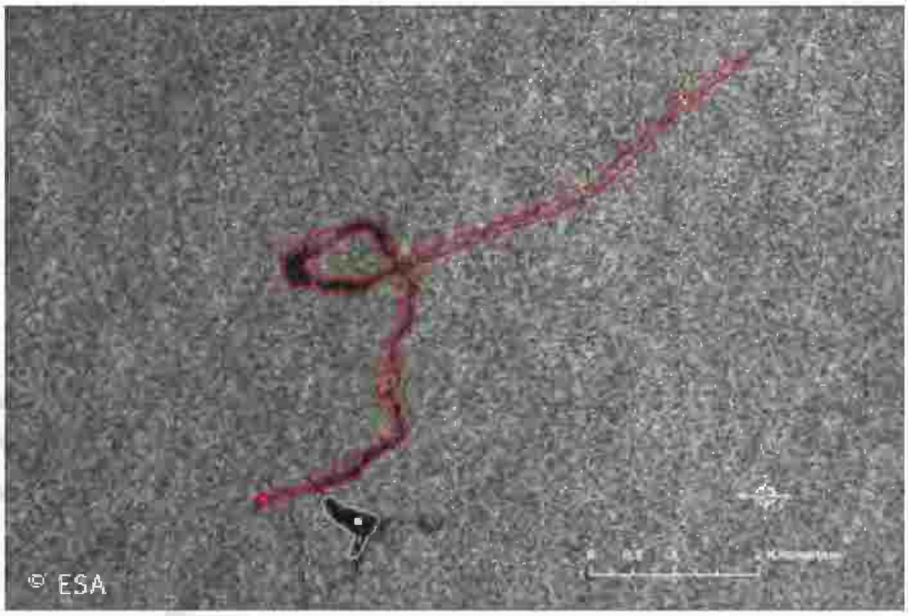


Figure 3.8: Possible seepage slicks identified offshore Indonesia (Biegert, 2007).

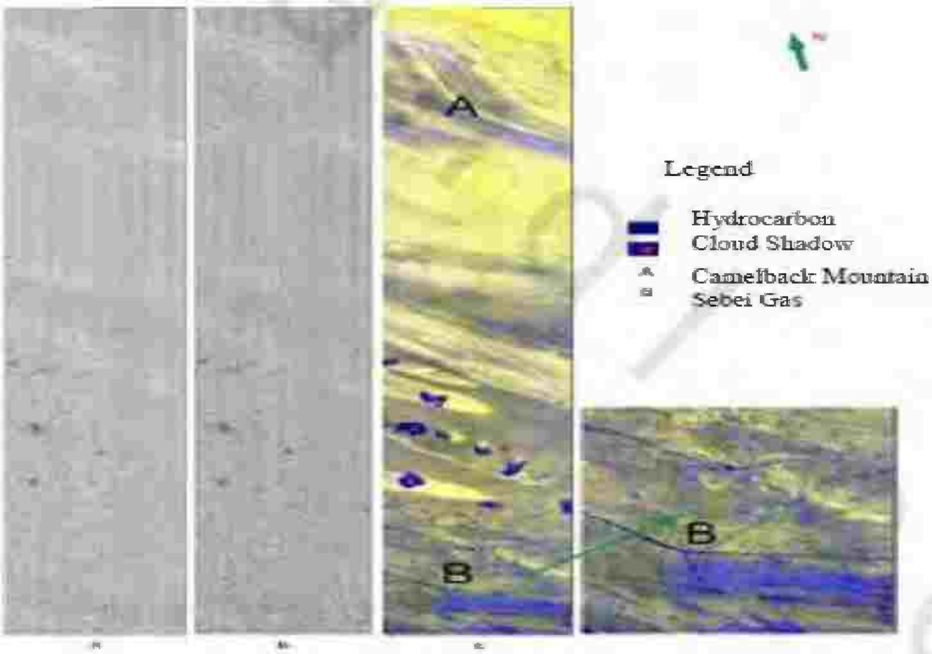


Figure 3.9: Extraction of Hydrocarbon Seeps. (Tian, 2012)

Oil and gas reservoirs hydrocarbon micro-leakage phenomenon is prevalently exist in theory. It is a comprehensive performance of multiple mechanisms transferring along various approaches, about 85% of oil and gas fields have the phenomenon of microleakage. Fig (3.9) shows that hydrocarbon microseepage areas, for which the blue hue region of the image stands, located obviously in two areas: the south SeBei Gas Field and the North Camelback Mountain gas-bearing structure of the study area. Given that hydrocarbon, concentration might be high in soil near gas field, and it is reasonable that there might be obviously hydrocarbon microseepage along the Camelback Mountain gas-bearing structure fraction, information concluded from the calculation coincides well with known the natural gas and anomaly gas distribution (Tian, 2012).

Predicting and mapping rock and soil alteration from satellite imagery is an accepted practice for mineral exploration, where heat and chemical changes from intrusions alter country rocks in phases that can be spectrally characterized and associated with ore.

Geochemical alteration is noted in rocks associated with hydrocarbon microseepage and changing pH, but relatively few investigations document this approach. It is proposed that hydrocarbon migration has altered surface rocks in Kurdistan as evidenced by digital image analysis of Landsat and ASTER satellite imagery.

Enhanced Landsat image of the Baba Dome portion of the Kirkuk oil field predicting altered exposures in pastel to white colors (above right). Resulting structural interpretation shows producing oil fields in pale green polygons and proposed alteration mineral models (lower left).

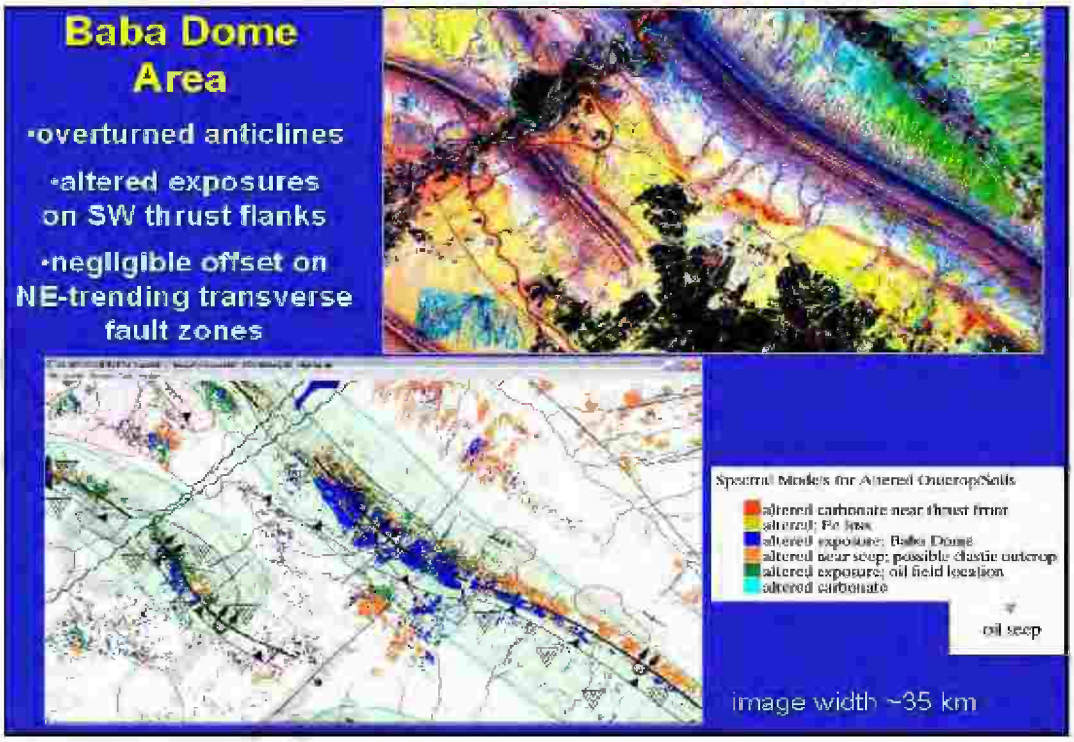


Figure 3.10: Enhanced Landsat image of the Baba Dome portion of the Kirkuk oil field. (Sandra et al, 2011)

Highly accurate stereo satellite elevation maps are being used in many phases of oil and gas exploration and development throughout the world. The benefits of the stereo satellite elevation mapping include surfacial and bedrock geologic mapping, improving the safety and the quality of onshore 3D seismic surveys, and planning and construction of onshore oil fields and the coastal facilities for offshore developments. Pipeline routes and oil and gas facilities are being planned and constructed using stereo satellite elevation mapping for horizontal and vertical control.

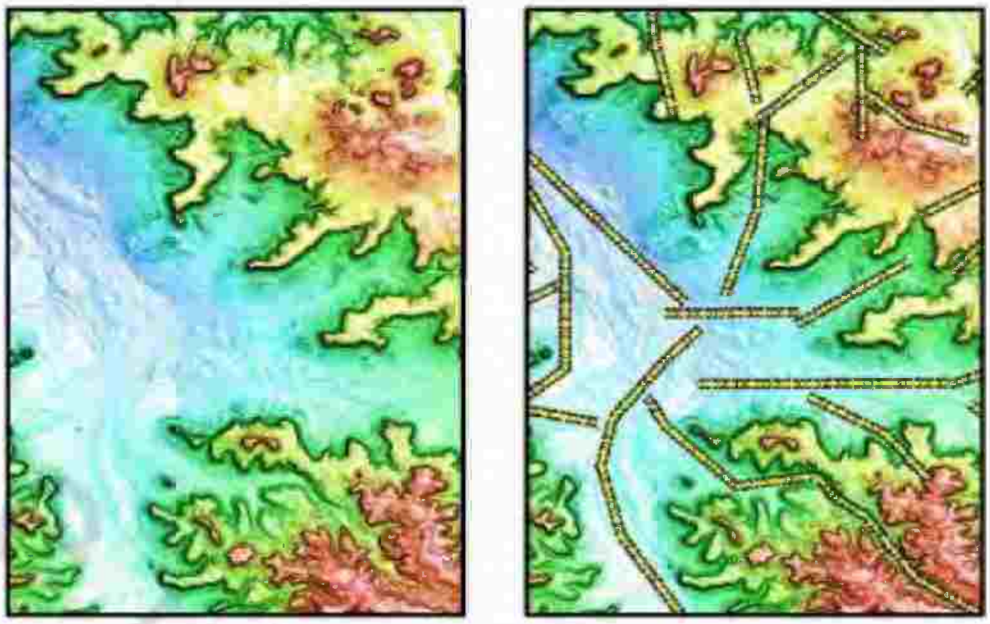


Figure 3.11.Stereo satellite elevation image. (Sandra et al, 2011)

Slope direction image of Fig (3.12) are clearly visible on the elevation image. Other faults are not clearly visible on the elevation image.

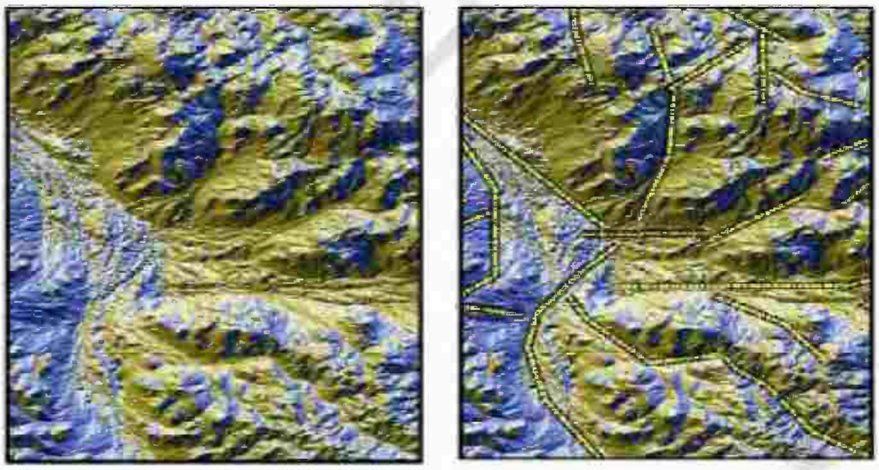


Figure 3.12. Slope direction image of a 200km^2 area in western Libya (Sandra et al, 2011).

This image is derived from the stereo satellite elevation mapping shown in Fig (3.11). The surface traces of subsurface structures are clearly defined on this image. Some of these structures are drawn on the image to the right.

Figure 3.13. WorldView 2 satellite ortho photo. (Sandra et al, 2011)

3.4 CASES DATA SUMMARY

The below table summarizes the data extracted from all selected cases for the principle of data analysis and ranking.

Table 3.21: cases data summery

Category	No
Seismic Survey Studies	10
non - Seismic Survey Studies	10
Land Area	12 desert
	2 rugged terrain
	1 forest
Water Areas	2 Ocean
	2 Sea
	1 River

Satellites images used for Land Areas :

IRS 1D LISS-III / IRS – 1D PAN / Landsat TM / Landsat ETM / Landsat 2 / Landsat 7 / Landsat ETM 7 / ASTER / Terra SAR – X / Radarsat – 2 / Hyperion hyperspectral /Worldview /GeoEye

Satellites images used for Water Areas :

NOAA – 11 / SAR / Landsat TM / Laser Flourosensors / Radarsat – 1 / ENVISAT

3.5 FACTORS RANKING

Factors ranking help and support the decision making in the projects that uses satellite images for oil exploration.

Ranking have two parts, the first is regarding the land section of projects like (Desert, wetlands) the second is regarding the water areas projects (Sea, Ocean, River).

Satellite images are categorized as: Single, multi source and multi temporal where:

- Single satellite image: this refers to the use of satellite image form only one source captured in a specific date.
- Multi source satellite images: also called Multi – sensor or Multi platform which refers to different satellite images captured from different sensors.
- Multi temporal data: are data captured at different times, this is very effective for change detection, data interval for change detection varied from few months to 5 years.

Ranking for Desert/ Wetlands (arranged from lower to higher)

1- Non -Seismic Study – Single.

2- Non- Seismic Study - multi temporal.

3- Non -Seismic Study - multi source.

4- Non - Seismic Study - multi source – multi temporal.

5- Seismic Study – Single.

6- Seismic Study - multi source.

7- Seismic Study - multi temporal.

8-Seismic Study - multi source – multi temporal.

Ranking for Sea /River/ Ocean (arranged from lower to higher)

1- Non -Seismic Study – Single.

2- Non- Seismic Study - multi source.

3- Non -Seismic Study - multi temporal.

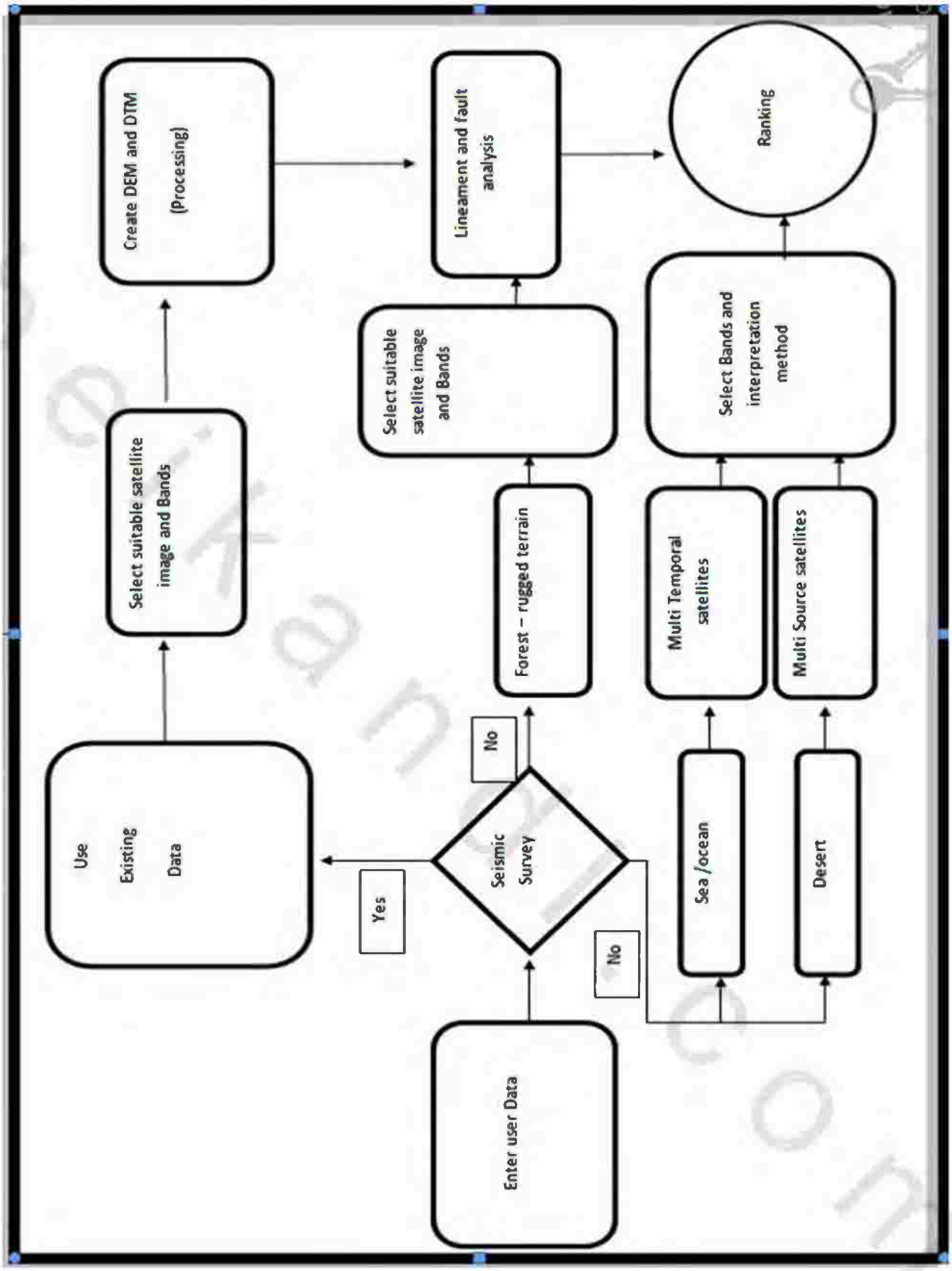
4-Non - Seismic Study - multi source – multi temporal.

3.6 RECOMMENDED OPTIMUM PATH FOR FINAL DECISION MAKER

The below flowchart describes different suggested processes of the use of remote sensing and other existing data for final decision making.

This chart will help to:

- Develop understanding of how the process is done.
- Study the process for improvement.
- Communicate to others how a process is done.
- When better communication is needed between people involved with the same process.
- Document the process.


Enter user Data
Seismic Survey
Yes
Use Existing Data
Select suitable satellite image and Bands
Create DEM and DTM (Processing)
No
Forest – rugged terrain
Select suitable satellite image and Bands
Lineament and fault analysis
No
Sea /ocean
Desert
Multi Temporal satellites
Multi Source satellites
Select Bands and interpretation method
Ranking

3.6.1 Work flow fine points

1-First step is the data collection and it is very important process.

2- The next step the decision if the study area has seismic data (2D or 3D) or not.

3- Option 1: the study area has seismic data, then the area type will be determined if it is desert area or sea/ocean or rugged terrain because each type will be directed to a different method of processing.

4-In case that we are working in a desert area it was strongly recommended to have 3 steps.

5- The first step is to use of existing data to create 3D models of the earth surface, and this will help with seismic data analysis to get a complete view about surface and subsurface data for the study area.

6- Second step is to select suitable satellite images and corresponding bands and most suitable interpretation methods according to project condition, then perform lineament and fault analysis to get fault locations overlaid on satellite image.

7- Third recommended step is to search about oil seepage or other indicators in the used satellite image.

8- Actually over 85% of oil basins include oil seepage or any other indictor.

9-The other selection of seismic survey data is when the study area is Sea or ocean, actually in most of the projects of water areas, it was recommended to have multi temporal satellite images, and if they are from different sources, this will be strongly supportive because of the change detection using multi temporal satellites will support the decision that the found indicators in satellite images (mainly seeps) which will be stable over time strongly indicate of subsurface oil existence.

10- The use of satellites of different sources support the decision that the interpreted objects found on different satellites giving the same result, ensures that oil is found in this place.

11-The use of satellite images for exploration in geologically complex and highly rugged terrains is always faced with difficulties, so the decision first is to detect tonal anomalies which may include change in vegetation or soil , this strongly indicate of oil existence.

12- Option 2: the study area has no seismic data (non – seismic survey), in this case the work process depends mainly on the satellite image in desert and water areas as the primary data source and then the analysis of any other existing data.

13- Once the study is based upon satellites, the decision for use more than one satellite is better because the first recommendation is the search for direct indicator, then performing any geological analysis if data is available.

14- The final step is to get the rank for the project and this will be a primary assessment for the suggested workflow.

3.6.2 Summary:

The work flow process has different options some are dependent on some user based and project condition, and the other are dependent on environmental and financial aspects.

The decision and steps now are clear for user to select the suitable path for supporting project decisions.