Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2013, Volume 2, Issue 1, pp. 198-204, Article ID Tech-71
ISSN 2320 - 0243

Review Article **Open Access**

Inventory of Liquefaction Area and Risk Assessment Region Using Remote Sensing

Shankar Lingam S.[1], Rajchandar Padmanaban[2] and Vinson Thomas[3]

[1]Regional Centre of Anna University of Technology, Tirunelveli, Tamil Nadu, India
[2]Institute for Geoinformatics, University of Muenster, Muenster, Germany
[3]Anna University of Technology, Chennai, Tamil Nadu, India

Correspondence should be addressed to Rajchandar Padmanaban, charaj7@gmail.com

Publication Date: 22 July 2013

Article Link: http://technical.cloud-journals.com/index.php/IJARSG/article/view/Tech-71

Abstract This proposed paper is focused on the identification of liquefaction areas for the communal protection and suggesting the suitable build up region to improve the inventory of areas .The water-logged sediments get loose up from the strong vibration of the earthquake causing liquefaction, so identifying the more vulnerable areas which become the source for the earthquake-related secondary effects, such as landslides, mud flow, ground subsidence and effects on human infrastructure should be considered gravely. The conventional methods used in analysis of liquefaction factor may be time consuming and really expensive, but the wide range of modern satellite imagery can easily be adopted for communal to access the bare earth and features, in the same advance used in this project for spotting the liquefaction areas which may cause various disaster/Land transform in future. Geographic Information Systems (GIS) and Remote Sensing methods along with the associated geo-databases can be assisted by local and national authorities to be better prepared and organized in providing infrastructure to the public. The assessment of satellite imageries, digital topographic data and Geo-data contribute to the attainment of the exact geologic and geomorphologic situation influencing the local site circumstances in an area and estimate all the probable damages that could happen. The main goal of this research is delineating the region which mainly corresponds to high liquefaction potential through the various Images processing technique and GIS analysis, using satellite imagery such as Landsat 7 ETM+ sensor and advanced space borne Thermal Emission and Reflection Radiometer (ASTER), collectively with different indices calculation, ground water table, digital elevation model, geomorphology and geological studies.
Keywords *Remote Sensing, Liquefaction Factor, Indices Computation, Multi Criteria Evaluation, Digital Image Processing, Geographic Information System Analysis*

1. Introduction

As we all know, the eternal fact about our Mother Earth is that the predominant movement of the tectonic plates. To be mentioned, this kind of activity is a nonstop aspect which actually does result in the displacement or the transferring of the continents in a very slow manner. But when this is in process, there are several factors like overlapping of the plates, clinging, drifting, elasticity etc., by their movements, that may happen that make it become clumsier which could as well result in some natural calamities such as earthquake, tsunami, volcanization etc., and when these occur, there are some other related secondary effects, such as landslides, mud flow, Ground subsidence and effects on human infrastructure that probably become the violent and worse environmental impacts. One among those secondary effects is the Liquefaction.

Liquefaction happens when the water-logged sediments get loose up from the strong vibration of the earthquake and such other hazards. The problem of liquefaction of soil during seismic event is one of the mentionable criteria in the field of Geotechnical Earthquake Engineering. Liquefaction of soil generally occurs in loose cohesion less saturated soil when pore water pressure increases suddenly due to induced ground motion and shear strength of soil decreases to zero and leading the structure situated above to undergo a large settlement, or failure. The failures take place due to liquefaction induced soil movement spread over few square km area continuously. The 8 types of failure commonly associated with soil liquefaction include sand boils, flow failures of slopes, lateral spreads, ground oscillation, loss of bearing capacity, buoyant rise of buried structures, ground settlements and failure of retaining walls.

And hence, this is a great problem where spatial variation involves and to represent this spatial variation, remote sensing technology and Geographic Information System (GIS) are very useful in analysing and decision making for the area being subjected to liquefaction. The resulting integrated paradigm of liquefaction analysis permits on focusing during the design phase on optimising the various elements of the design by incorporating the spatial component of the geotechnical data explicitly in the analysis.

2. Data and Description

A remote sensing image provides the wider range of synoptic segment of features about earth surface widely used in recognizing various parameters which can be useful for various analysis and interpretation. The elite capabilities of satellite based sensors in providing a wide-ranging spectrum of information accessible through the electromagnetic spectrum in recurring and synoptic coverage over in accessible and larger areas in recurrent intervals made the Remote Sensing technology an effectual tool, this advanced technology can be useful for inventory of liquefaction area and accessing risky region. Here in this paper, two types of satellite data are taken into account so as to analyse the liquefaction susceptible area and they are Landsat ETM+ data and ASTER data.

2.1. Aster Data

The Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) is an imaging instrument onboard Terra, the flagship satellite of NASA's Earth Observing System (EOS) launched in December 1999. ASTER data is used to create detailed maps of land surface temperature, reflectance, and elevation. Its main goal is improving a scientific understanding of the Earth as an integrated system, its response to change, and to better predict variability and trends in climate, weather, and natural hazards. The Table 1 shows the characteristic of ASTER data.

***Table 1**: Technical Characteristics of ASTER Data*

Subsystem	Band Number	Spectral Range(μm)	Radiometric Resolution	Absolute Accuracy (σ)	Spatial Resolution	Signal Quantization
VNIR	1	0.52-0.60	NE Δρ ≤ 0.5%	≤ 4%	15m	8 bits
	2	0.63-0.69				
	3N	0.78-0.86				
	3B	0.78-0.86				
SWIR	4	1.600-1.700	NE Δρ≤ 0.5%	≤ 4%	30m	8 bits
	5	2.145-2.185	NE Δρ ≤ 1.3%			
	6	2.185-2.225	NE Δρ ≤ 1.3%			
	7	2.235-2.285	NE Δρ ≤ 1.3%			
	8	2.295-2.365	NE Δρ ≤ 1.0%			
	9	2.360-2.430	NE Δρ ≤ 1.3%			
TIR	10	8.125-8.475	NE ΔT ≤ 0.3 k	≤ 3K(200-240K)	90m	12 bits
	11	8.475-8.825		≤ 2K(240-270K)		
	12	8.925-9.275		≤ 1K(270-340K)		
	13	10.25-10.95		≤ 2K(340-370K)		
	14	10.95-11.65				

2.2. Landsat Enhanced Thematic Mapper plus Data

Landsat Thematic Mapper (TM) is a multispectral scanning radiometer that was carried onboard Landsat 4 and 5. The TM sensors have been providing nearly continuous coverage since July 1982 till now. The Landsat Enhanced Thematic Mapper (ETM) was introduced with Landsat 7. ETM data cover the visible, near-infrared, shortwave, and thermal infrared spectral bands of the electromagnetic spectrum.

The Landsat Project is a joint initiative of the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA) [1,2]. Landsat's Global Survey Mission is embarked to establish and execute a data acquisition strategy that ensures repetitive acquisition of observations over the Earth's land mass. The Enhanced Thematic Mapper Plus (ETM+) instrument is a fixed "whisk-broom", eight-band, multispectral scanning radiometer capable of providing high-resolution imaging information of the Earth's surface. It detects spectrally-filtered radiation in VNIR, SWIR, LWIR and panchromatic bands from the sun-lit Earth in a 183 km wide swath when orbiting at an altitude of 705 km.

3. Methodology

In concern to the method of approach suggested in this paper, there are 3 main steps viz. Image processing, GIS analysis and interpretation and map generation that are to be handled broadly in order to delineate the task absolutely and optimistically. The imagery data for the analysis are obtained from two major sensors viz. Landsat ETM+ and ASTER and are processed with ERDAS 11.0.4/ENVI 5 image processing software for the effective progress .The well processed image is then calibrated and corrected using Radiometric/Geometric calibration.

3.1. Radiometric Correction

The process of radiometric correction involves 3 steps, initially the DN (digital number) values recorded by the sensor are converted to spectral radiance (at the sensor) after processing DN values [3], the converted spectral radiance is further converted to apparent reflectance (at the sensor) and finally removal of atmospheric effects due to absorption and scattering is done (atmospheric correction) and providing the reflectance of pixels at the Earth's surface.

3.2. Geometric Correction

The Geometric calibration process involves different levels of correction to the remotely sensed imagery viz. Registration, Rectification, Geocoding and Ortho-rectification. The alignment of one image to another of the same area is done with the process of registration [4]. In rectification, the alignment of image to a map is done so that the image turns out to be planimetric, just like the map. Rectification can also be termed as geo-referencing. Geocoding is a special case of rectification that adds in scaling to a uniform standard pixel GIS. The use of standard pixel sizes and coordinates authorizes convenient layering of images from sensors and maps into GIS. Ortho-rectification is the correction of the image, pixel by pixel for topographic distortion done making the image to be in a strict orthographic projection.

3.3. DEM Generation

DEM generation described below requires the application of PHOTOMOD 4.4 software. Digital Elevation Model abbreviated as DEM is essential to handle wide tasks notably generating contour lines and ortho images, erosion control, agricultural developments, flood planning, 3D-views, visibility checks and other such norms. The initial move in the satellite data processing is focused on the stereo orientation which could be achieved by creating a catalogue of the Ground Control Points (GCP's) identified using photo interpretation. TIE points are added on both images to perform the Block adjustment, so as to improve the positioning, fix the deformations and reduce the shift between the images [5]. The resultant is the precise positioning of the stereo pair with regards to the GCP’s.

DEM is obtained using TIN (Triangular Irregular Network). The pickets are created over an 8 meter grid using the adaptive method that calculates 3D coordinates for points being the most correlated with each grid node of the TIN nodes coordinate. The final TIN is triangulated from grid nodes with the modified Delaunay algorithm. Different methodologies including photo interpretation, insertion of break lines are to be integrated with the purpose of enhancing the model. The table containing the GPS measurements is formatted as input file to Photomod to facilitate as TIN break lines [6]. Pickets, from which the TIN is generated, are exported from the Photomod and imported into the GIS project (ESRI ArcMap 9.3).

The outcome of the analysis of height distribution of the points to find the anomalies is verified manually using photo interpretation. After the pickets are controlled and modified, they are again imported into Photomod to generate an optimized TIN. The DEM is then generated from the TIN. The high spatial resolution of the satellite image would enhance the quality of the DEM. With the intension of maintaining a uniform representation of the territory, a smoothing technique is applied. The final result is compared with the GPS measurements gathered, proving the effectiveness of the methodology and validating the high degree of accuracy of the DEM.

3.4. Indices Calculation

An image processing apparatus includes a processing amount index calculation unit configured to analyze content of image data that is independent of print resolution and to calculate a processing amount index indicating a processing amount necessary in converting the image data into a bitmapped image, a storing unit configured to store the calculated processing amount index as additional information associated with the image data, and a sending unit configured to send the image data and the additional information [7]. Here 5 indices are identified to delineate the liquefaction factor as Simple ratio, NDVI, TNDVI, SAVI and MNDWI.

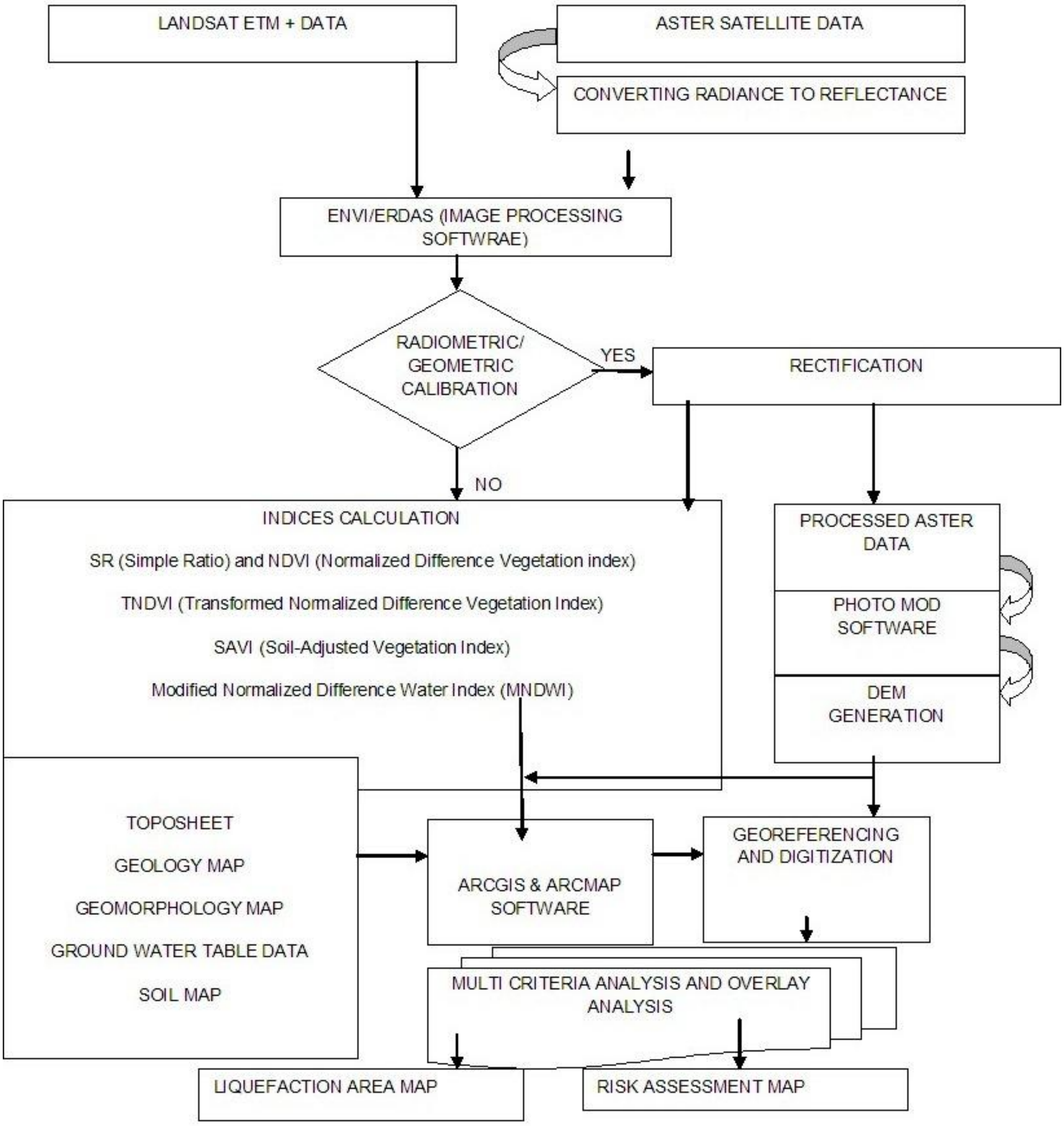

Figure 1: *Work Flow of Inventory of Liquefaction Area and Risk Assessment Region*

3.4.1. SR (Simple Ratio)

It is the ratio of the highest reflectance; absorption bands of chlorophyll makes it both easy to understand and effective over a wide range of conditions. As with the NDVI, it can saturate in dense vegetation when LAI becomes very high. Its value ranges from 0 to more than 30 [8]. SR is defined by the following equation no 1:

$$\mathbf{SR} = \rho_{NIR} / \rho_{RED} \text{ ---------- Eqn 1}$$

3.4.2. NDVI (Normalized Difference Vegetation Index)

It is the most frequently used vegetation index and the combination of its normalized difference formulation and use of the highest absorption and reflectance regions of chlorophyll make it robust over a wide range of conditions. Its value ranges from -1 to +1 [9,10]. The equation 2 shows the NDVI calculation.

NDVI = $\rho_{NIR} - \rho_{RED} / \rho_{NIR} + \rho_{RED}$ ---------- Eqn 2

3.4.3. TNDVI (Transformed Normalized Difference Vegetation Index)

TNDVI stands for Transformed Normalized Difference Vegetation Index. This index has a more complex ratio form for calculating the vegetation but still only uses Band 3 and Band 4. The equation 3 shows the TNDVI calculation [11].

[(Band 4 - Band 3) / (Band 4 + Band 3) +.5] ^ (1/2) --------- Eqn 3

(Or the square root of ([Infrared - Red] / [Infrared + Red] + .5)

3.4.4. SAVI (Soil-Adjusted Vegetation Index)

SAVI is a hybrid between a ratio index (NDVI) and a perpendicular index (PVI) [12]. Its equation is

SAVI = ((NIR-Red) / (NIR + Red+ L)) * (1+L) ---------- Eqn 4

L is a correction factor and its value is dependent on the vegetation cover. For total vegetation cover it receives a value of zero, effectively turning SAVI into NDVI. For very low vegetation cover, it receives the value of 1.

3.4.5. MNDWI (Modified Normalized Difference Water Index)

NDWI was unable to completely separate built-up features from water features. NDWI showed positive values in built-up features which were similar to water because the NIR reflectance was lower than the green reflectance [13]. To compensate the drawbacks of NDWI, overcome by Modified NDWI.

3.5. Multicriteria Analysis

GIS is capable of analysing several criteria utilizing spatial and attribute data. With a view to the Multicriteria evaluation, which is nothing but the process of evaluating the spatial features weighing them by allocating values to each pixel owing to their actual properties with the guidance of weighted Overlay Analysis, The weightage to every pixel is determined and it is performed in raster maps to create parametric thematic maps. For the task of delineating the liquefied zones, weighing the 4 statistical zones is done registering their values from 1 to 4 say, 1 for non-liquefaction susceptible zone, 2 for low-liquefaction susceptible zone, 3 showing moderate liquefaction susceptible zone and the final 4 indicating high-liquefaction susceptible zone. These different strengthened zonal parameters are thus created and attributed to compile the Liquefaction Area Map.

3.6. Overlay Analysis

Overlaying hereby probably determines the merging of differently featured imagery maps of the same or part of the same area, immersing them into a single compact monotonic data getting the idea of their spatial relationship. Weighing average is finally performed to every individual layer of parameters identifying the hot spots or high liquefaction area, so as to generate the Risk Assessment Map.

4. Conclusion

The above proposed criterion will surely be time and cost efficient and one among the successful ways of approach that tends to bear the stress of the researchers and geotechnical engineers so as to assess the environmental impacts and geotechnical hazards. This will probably pave the way for further improvement in emerging the strategic ideas and techniques in these kinds of inventory works. Thus the compilation and generation of the Map with the delineation of the liquefaction susceptible zones over the study area which is the prime motto of this review can be done in an absolute manner with the above prescribed methodology utilizing the remote sensing and Geographical Information System (GIS) technologies and overall accurate and well-organized output can be obtained without any degree of failure to the attempt pursued. This henceforth makes an enthusiastic belief subjected to the expected output and may help and support the communal developers and the government in further planning of the towns and cities and designing of their infrastructure in an effective and brawny way.

References

1. Ferdinent, J.; Padmanaban, R. Development of a Methodology to Estimate Biomass from Tree Height Using Airborne Digital Image. *Int. J. Adv. Remote Sens. GIS* **2013**, *2*, 49–58.

2. Padmanaban, R. Location Privacy in Location Based Services: Unsolved Problem and Challenge. *Int. J. Adv. Remote Sens. GIS* **2013**, *2*, 398–404.

3. Visalatchi; Padmanaban, R. Land Use and Land Cover Mapping and Shore Line Changes Studies in Tuticorin Coastal Area Using Remote Sensing. *Int. J. Remote Sens.* **2012**, *1*, 1–12.

4. Monishiya, B. G.; Padmanaban, R. Mapping and change detection analysis of marine resources in Tuicorin and Vembar group of Islands using remote sensing. *Int. J. Adv. For. Sci. Manag.* **2012**, *1*, 1–16.

5. Ferdinent, J.; Padmanaban, R. Development of a Methodology to Estimate Biomass from Tree Height Using Airborne Digital Image. *Int. J. Adv. Remote Sens. GIS* **2013**, *2*, 49–58.

6. Padmanaban, R. Integrating of Urban Growth Modelling and Utility Management System using Spatio Temporal Data Mining. *Int. J. Adv. Earth Sci. Eng.* **2012**, *1*, 13–15.

7. Padmanaban, R.; Kumar, R. Mapping and Analysis of Marine Pollution in Tuticorin Coastal Area Using Remote Sensing and GIS. *Int. J. Adv. Remote Sens. GIS* **2012**, *1*, 34–48.

8. Venkatesan G; Padmanaban, R. Possibility Studies and Parameter Finding for Interlinking of Thamirabarani and Vaigai Rivers in Tamil Nadu , India. *Int. J. Adv. Earth Sci. Eng.* **2012**, *1*, 16–26.

9. Padmanaban, R. Modelling the Transformation of Land use and Monitoring and Mapping of Environmental Impact with the help of Remote Sensing and GIS. *Int. J. Adv. Altern. Energy, Environ. Ecol.* **2012**, *1*, 36–38.

10. Padmanaban, R.; Sudalaimuthu, K. Marine Fishery Information System and Aquaculture Site Selection Using Remote Sensing and GIS. *Int. J. Adv. Remote Sens. GIS* **2012**, *1*, pp 20-33.

11. Green, E. P.; Mumby, P. J.; Edwards, A. J.; Clark, C. D.; Ellis, A. C. Estimating leaf area index of mangroves from satellite data. *Aquat. Bot.* **1997**, *58*, 11–19.

12. Cabral, P.; Zamyatin, A. Three Land Change Models for Urban Dynamics Analysis in Sintra-Cascais Area. *Image Rochester NY* **2006**, 2–3.

13. Kovacs, J. M.; Wang, J.; Flores-Verdugo, F. Mapping mangrove leaf area index at the species level using IKONOS and LAI-2000 sensors for the Agua Brava Lagoon, Mexican Pacific. *Estuar. Coast. Shelf Sci.* **2005**, *62*, 377–384.