INTEGRATED REMOTE SENSING AND GIS IN LINEAMENT MAPPING FOR GROUNDWATER EXPLORATION – A CASE STUDY IN AMBALANTOTA, SRI LANKA

W. L. Weerasekera, B. B. Mayadunna, I.P. Senanayake, D.M.D.O.K. Dissanayake

Department of Earth Resources Engineering, University of Moratuwa, Moratuwa, Sri Lanka.
Email: wlakshaniw@gmail.com, bhagyamayadunna@gmail.com,
indishes@uom.lk, dmdok@earth.mrt.ac.lk

ABSTRACT

Geologic lineaments, which can be detected by integrated GIS and image processing techniques, play a significant role as an influential factor in a GIS model designed for mapping groundwater potential. Though lineaments are hard to map in the field, satellite/ aerial remote sensing and GIS techniques can be effectively utilized in this endeavour. Automatic and manual extraction methods were utilized in this study to delineate lineaments from the digital terrain model (DTM) and satellite images covering the study area, Ambalantota. Enhanced bluff topographic illumination under varied light directions enables interpretation of lineaments from DTMs effectively. For the automatic lineament extraction, eight shaded relief images were generated using the DTM and subsequently compressed into two resultant images with multi-directional light. Afterwards, a combined image was developed using the two resultant shaded relief images and the edge enhanced image was developed by employing Canny edge detection algorithm. Subsequently, a binary image was obtained by applying a threshold to the resultant edge enhanced image. Finally, curve extraction function was utilized for the automatic extraction of lineaments from the binary image.

Several image enhancement techniques viz. filtering, principal component analysis (PCA), spectral rationing and colour composites were respectively employed in manual extraction of lineaments from Landsat 7 ETM+ image of the study area. Afterwards, lineaments were manually digitized with the aid of tonal variations of the processed image.

The results depict a precision level of 75% between automatic and manual lineament extraction methods.

Key words: Digital terrain model, GIS, image enhancement, lineaments

1. INTRODUCTION

Extended mappable linear or curvilinear features of a surface whose parts align in straight or nearly straight relationships that may be the expression of folds, fractures or faults in the subsurface are defined as lineaments [1]. Geologic lineament mapping contributes in problem solving in a number of engineering applications such as site selection for constructions (dams, bridges, roads, etc.), hydrogeological research, seismic and land risk assessment, mineral exploration, hot spring detection, etc. [2, 3, 4].

Studies on geologic lineaments have revealed a close relationship with groundwater flow and yield [1, 5, 6]. Lineaments are often associated with weathered zones, hence increasing permeability and porosity consequently broadening groundwater prospects.

Delineating lineaments through integrated remote sensing and GIS techniques has been commonly practised over last two decades. In this study, lineaments were delineated using two distinct methods, viz. automatic and manual lineament extraction, followed by comparison of the two resultant layers.

The objective of this study is to verify the capability of remote sensing and GIS techniques to extract lineaments automatically and manually.

2. METHODOLOGY

Ambalantota divisional secretariat of Hambantota district was chosen as the study area in this research considering periodic water stress conditions experienced by the area. The area covers approximately 319 km^2 and bounded by latitudes $80^0\ 53' - 81^0\ 02'$ E and longitudes $6^0\ 04' – 6^0\ 15'$ N. Though the average annual rainfall of Ambalantota fluctuates within the range of 889 mm -1016 mm; rainfall drops down significantly from January to March and from June to August [7]. Water management plays a vital role in the economy of the area, since agriculture is the main livelihood.

2.1 Automatic lineament extraction

For automatic lineament extraction DTM of Ambalantota was generated using ASTER Global DEM which is a product of METI and NASA.

Eight shaded relief images were generated considering eight contrast illumination directions of 0^0, 45°, 90°, 135°, 180°, 225°, 270° and 315° as the initial step in automatic extraction method. Subsequently, eight shaded relief images were compressed into two layers of azimuth angle (0°, 45°, 90° and 135°) and (180°, 225°, 270° and 315°). Afterwards, the two resultant layers were combined on a GIS platform. Canny edge detection algorithm was applied to the resultant combined shaded relief image to produce an edge enhanced image through a Gaussian filter. A binary image was subsequently obtained by applying an appropriate threshold value to the edge enhanced image considering the minimum gradient level for an edge pixel.

The resultant binary image was used to extract the curves and lineaments considering minimum length of curve to be considered as lineament, maximum angle between segments for them to be linked and minimum distance between the end points of two vectors for them to be linked. Subsequently, manmade linear features such as roads, bridges and dams were masked from the resultant layer.

Figure 1 illustrates the methodology adopted to delineate lineaments from automatic extraction method.

2.2 Manual lineament extraction

Landsat 7 ETM + images covering the study area were used as raw data for the manual lineament extraction process. Manual lineament extraction encompasses of several image enhancement techniques, viz. principal component analysis (PCA), spectral rationing, colour compositing and spatial filtering [8, 9]. Figure 2 illustrates the process adopted in manual extraction.

PCA was used to compress the information in six Landsat 7 ETM + image bands (band 1, 2, 3, 4, 5 and 7) into three layers.

Two sets of band ratio images were developed for manual lineament extraction. The first set encompasses of band ratios 5/7, 2/3 and 4/5, while the second set encompasses of band ratios 5/7, 5/1 and (5/4*3/4). Subsequently, two RGB composites were prepared by using respective ratio images.

Colour composite technique was used to enhance the interpretability of data. Optimal geologic information depiction in colour composite imageries lies upon the selection of the three most suitable channels [8]. After examining different combinations, 7, 4, 1 and 4, 3, 2 were found as the best band combinations in identifying linear patterns of geologic formation boundaries, river channels, manmade features and vegetation patterns.

Spatial filtering operations can selectively enhance the boundaries of different spatial features in a satellite image. In this study, directional Gradient-Sobel and Gradient-Prewitt edge detection operators were applied on Landsat image (band 7) in N-S, E-W, NE-SW and NW-SE directions in order to identify the lineaments in the particular directions (Table 1) [8].

Finally, all the resultant layers obtained through image enhancement techniques were manually digitized to develop the final lineament map (Figure 2).

Table 1: Sobel and Prewitt filters applied in four directions (*Source: [8]*)

Filter	N-S	NE-SW	E-W	NW-SE
Sobel	-1 0 1 -2 0 2 -1 0 1	-2 -1 0 -1 0 1 0 1 2	-1 -2 -1 0 0 0 1 2 1	0 1 2 -1 0 1 -2 -1 0
Prewitt	-1 0 1 -1 0 1 -1 0 1	-1 -1 0 -1 0 1 0 1 1	-1 -1 -1 0 0 0 1 1 1	0 1 1 -1 0 1 -1 -1 0

3. RESULTS AND DISCUSSION

Eighty four lineaments were identified using automatic extraction method. Occurrence of lineaments in NW-SE direction is visually frequent in the automatically extracted lineament layer.

One hundred and thirty eight lineaments were delineated through manual extraction method.

Visual comparison of two resultant layers depicted that higher number of lineaments were identified in manual extraction method. Yet, the probability of detecting smaller lengthen lineaments is higher in automatic lineament extraction method.

Further, the results depict that the spatial distribution and orientation of the lineaments delineated by both methods are considerably identical.

4. CONCLUSION

Spatial distribution of the resultant layers of manual and automatic lineament extraction methods are 75% identical depicting a high level of precision. Automatic lineament extraction method can be inferred as more suitable for lineament mapping considering its time effectiveness and user friendliness compared to the manual extraction method.

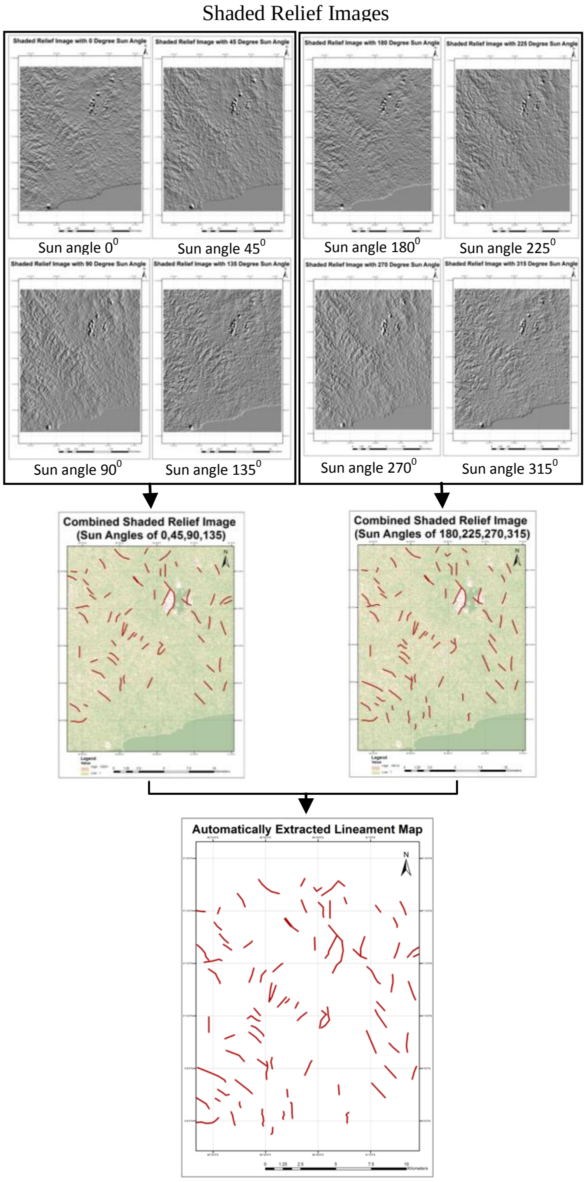

Figure 1: Delineating lineaments in Ambalantota, Sri Lanka using automatic extraction method

5. REFERENCES

[1] Baskaran, R. and Pothira,j P. (2013) *"Mapping of lineaments for groundwater targeting and sustainable water resource management in hard rock hydrogeological environment using RS- GIS"*, Ray P. and Zhang Y.,(ed.) *Climate Change and Regional/Local Responses*.

[2] Talabi, A. O. and Tijani, M. N (2011) "*Integrated remote sesning and GIS approach to groundwater potential assessment in the basement terrain of Ekiti area southwester Nigeria*". Vol. 58, No 3, pp 303-328

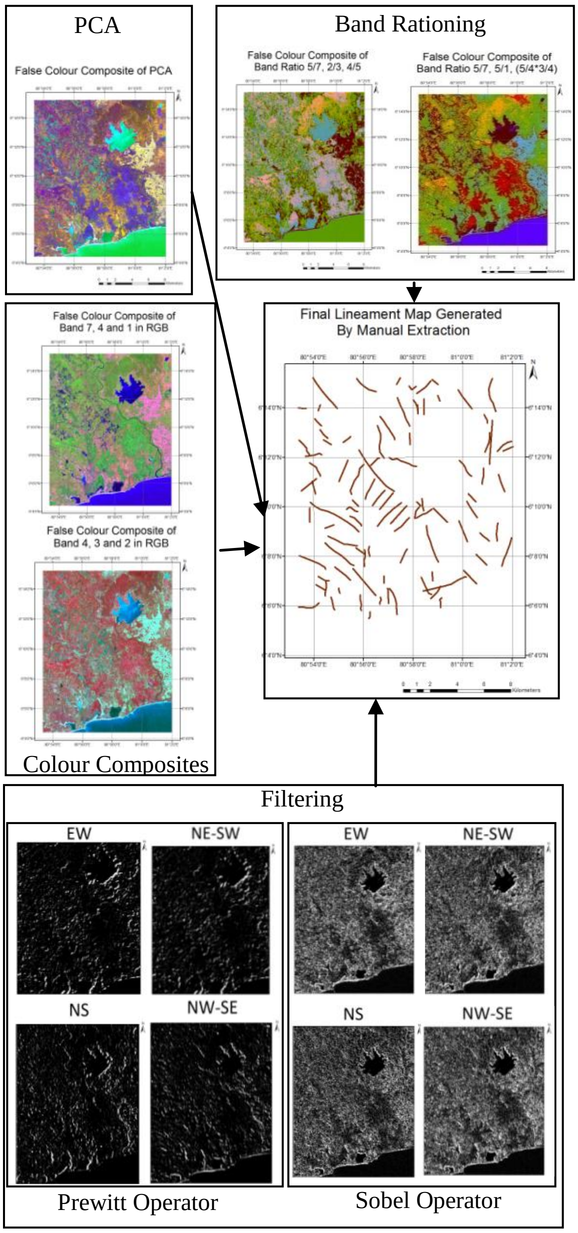

Figure 2: Delineating lineaments in Ambalantota, Sri Lanka using manual extraction method.

[3] Bernard, E. H., Thomas, J. M. and Allyson, L. T. (2012) "*Lineament analysis of mineral areas of interest in Afganistan*". USGS Afghanistan Project Product No. 233

[4] Demetre, A., Ourania, M. and Marianthi, S. "*Automatic mapping of techtonic lineaments (fault) using methods and techniques of photointerpretation/ digital remote sensing and expert systems*". No 1174

[5] Mabee, S. B, Hardcastle, K.C, & Wise, D. U. (1994) "*A method of collecting and analyzing lineaments for regional-scale fractured-bedrock aquifer studies*". Groundwater 32(6), 884-894

[6] Magowe, M. & Carr, J. R. (1999) "*Relationship between linemanets and groundwater occurrence in western Bostwana*". Groundwater 37(2), 282-286.

[7] Senanayake, I.P., Welivitiya, W.D.D.P., Nadeeka, P.M., Puswewala, U.G.A. and Dissanayake, D.M.D.O.K. (2013) "*Remote sensing and GIS based assessment of water scarcity: A case study from Hambantota district, Sri Lanka*", ACRS, Bali, Indonesia, 2478-2485.

[8] Sarp, G. (2005) "*Lineament Analysis From Satellite Images, North-West of Ankara*" *(thesis)* The graduate school of natural and applied sciences, Middle East.

[9] Ali E.A., El Khidir S. O., Babikir I. A. A. and Abdelrahman E.M. (2012) "*Landsat ETM+7 digital image processing techniques for lithological and structural lineament enhancement: Case study around Abidiya area, Sudan*", *The Open Remote Sensing Journal*.

[10] Anwar A., Juhari M. A. and Ibrahim A., "*Automatic mapping of lineaments using shaded relief images derived from digital elevation model (DEMs) in the Maran Sungi Lembing area, Malaysia*", 2010.

[11] Mahmud M. M. and Abdullah H. A., "*Automatic mapping of lineaments using shaded relief images derived from digital elevation model (DEM) in Kurdistan, Northeast Iraq*"