COMPARATIVE CLASSIFICATION TECHNIQUES IN GEOSPATIAL ANALYSIS: DEFENCE APPLICATION

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Abstract
Terrain and land-use analysis are an integrated component of various planning and policy decisions. Classification based on statistical methods like supervised and unsupervised methods provide results with limited accuracy because of their inherent limitations of dependence on radiometric values. Rule based methods for object based classification for feature extraction produces better results for high resolution imagery. This paper intends to compare advantages and accuracy of using object based image classification techniques with such legacy classification methods. It also explores possibility of applying object based techniques for terrain / land-use feature extraction at two similar terrain sites using same rule set. The resultant outputs are characterized and compared from the perspective of defence operations in unfamiliar terrain at different locations.

Keywords: *Classification, Object based classification, Supervised, Unsupervised, Terrain Analysis.*

Introduction

Terrain analysis for planning, decision making in the defence sector has been an area of constant progression. The implementation of Geospatial and image based information extraction and analysis plays a crucial role in reconnaissance, battlefield intelligence, where time critical missions and decision making are important. It involves administration, policy, operational, strategic and tactical requirements. Digital Image classification methods have been used to expedite generating the land-use and terrain features with substantial accuracies. In this paper different classification methods were implemented for the same purpose in hyper-arid barren land of Middle-East using optical datasets belong to two different area with similarity in terrain. The output of conventional methods like pixel-based as well as object based classifications outputs are compared keeping in mind the operational need. The objective of this study is to develop an object-oriented information extraction method to increase land cover information extraction and to provide rapid, large-scale land cover data for defense requirement.

Test Datasets

The study is carried out using two sites located at Negev desert at Israel and eastern Sinai peninsula in Egypt. Site-A is located at SW of dead-sea and about 70 Km southwards of Beersheba city. It is south of Mizpe Raman and west of Paran, Arava valley. Site B is located in eastern Sinai of Egypt at 40 km SE of Hasna. Sentinel-2A cloud-free False Color Composite dataset combining 8 (.842µm NIR), 4 (.665µm Red) and (.490 µm Blue) bands-with 10 m resolution is used for the study. As the area is representing a typical hyper arid rocky desert terrain and almost devoid of vegetation blue Band is given preference for FCC and above mentioned are chosen. Both the data-sets are in UTM projections and WGS-84 datum. Additional supportive digital elevation model (DEM) datasets with 30m resolution (downloaded from Jaxa website) is used for analyzing the heights of the area.

Table 1. Details of study area A (Negev Israel) and B Eastern Sinai

	Site	Co-ordinate	Date	Area	Area
1	A	30° 14’ 47” to 30° 36’ 39” N and 34° 37’ 6” to 35° 10’ 36” E	19.3.18	Negev, Israel	55 X 46 km ~ 2106 Sq Km
2	B	29° 36’ 53” to 28° 58’ 58” N and 34° 7’34” to 33° 24’ 06 “ E	3.9.18	Eastern Sinai, Egypt	69 X 80 km ~ 5220 Sq Km

Study area

The Negev and Sinai (Fig- 1) belong to similar geographical unit subdivided by international border of Egypt and Israel. The Negev is a rocky desert. Site A belongs to central Negev high plateau region and is at the fringes of Arbah valley along the Jordanian border, (Fig. 2a and b) the topography is hyper-arid desert undulating terrain with elevation upto 3000 m.

Fig-2a. Sentinel - 2A FCC imagery of Study area A Fig - 2b. Colour coded Digital elevation Model

The area depicts rocky mountains interrupted by Wadis (dry riverbeds), salt and limestone crusts and deep craters known as Maktesh (typical of Negev desert of Israel and the Sinai Peninsula). At the northern part prominent landforms is Maktesh Raman (largest in Israel) having steep walls of resistant rock surrounding a deep closed valley (seen at NE part in Fig-2a) , drained by a two wadis namely Nahal Raman and Nahal Ardan. Maktesh Raman is 38 km long and 2 to 8 km wide and 500m deep. West of this crater, at the NW of study area the elevation is 1031m which is part of Negev highland. Many non-perennial channels originated (dry at most of the time of the year) and the wadis (valley) are extending from east to west cutting across the rocky area characterized by high surface runoff-during rain. The area has sparse vegetation and contains a variety of igneous and metamorphic types. Further south the study area is characterized by low sand stone hills and plains. Central part of study area is characterized by desert plateaus(broad and flat highlands with a mantle of loess), broken by dry gorges and cliffs of sandstone and stony deserts. The southern Negev desert has large part of flat and weathered, gravelly alluvial surfaces (Stony Deserts) that are characterized by Reg soil development outwash sheets (Cook and Warren, 1973; Dan et al., 1982; Gerson et al., 1985). Reg soils typically have a high salinity content, are dust-rich, and exhibit a one to two particle thick surface cover of pebble-size clasts that form darkly varnished desert pavements. Paran Plains, exists at further south(elevation 400- 500 m),is an alluvial plain desert pavement with moderately varnished coatings on clasts. Loose, clay loam gypsum and calcic accumulation of alluvium depositions are found at SE side of study

The area has an arid climate, characterized by cold winter and hot dry summer (extreme) with mean annual summer temperature of 35 - 42 degree C and winter temperature of 20-22 degree C. It receives 100 mm of rain per year, with inferior and partially salty soils (Fig-3). The Arabah Valley, a savanna region with average annual rainfall is >1”, grow some fruit and vegetables with modern farming techniques. Sentinel data of study area- A (Fig- 2a) indicate that a large proportion of the area is covered by bare soil with very minimum vegetation and sparse agricultural farms of crops and orchards.

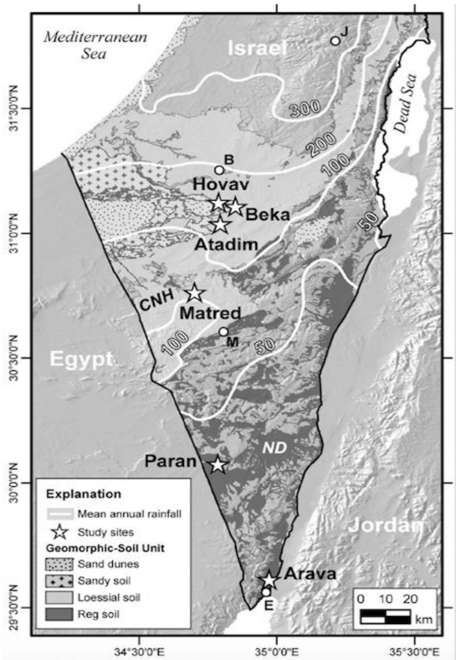


Figure 3. Geomorphology map (open source) study area-A Figure 4. Sentinel -2A FCC imagery of Study area B area.

Methodology

The image is inspected through visual interpretation for understating the terrain features using different bands and for band selection. The FCC image is digitally classified for pixel based (using Erdas Imagine 14) and object based classification (using and e-Cognition S/W Ver. - 9). The results of different classifications are compared. The primary difference between pixel based and object based classification is that the ability of object based digital classification is conceptually linked with classification of objects based on several parameters rather than only color or spectral values.

Pixel based Classifications - In these conventional classifications each pixel is classified separately to the most appropriate thematic class based on pixel's spectral signature. Unsupervised Classification is performed using K-means clustering (with 15 clusters) and Isodata clustering are performed (15 classes with 10 iterations and 0.95 convergence ratio). Classes are later combined in 7 classes which are representative and typical for the particular land-use class. Supervised maximum likelihood Classification is performed for 7 classes using Training samples with synchronization of ground information representing typical land use features. Majority filter with 4 neighborhoods is applied on the classification results of Unsupervised and Supervised classifications results to remove the salt and pepper effects.

Object based Classification-

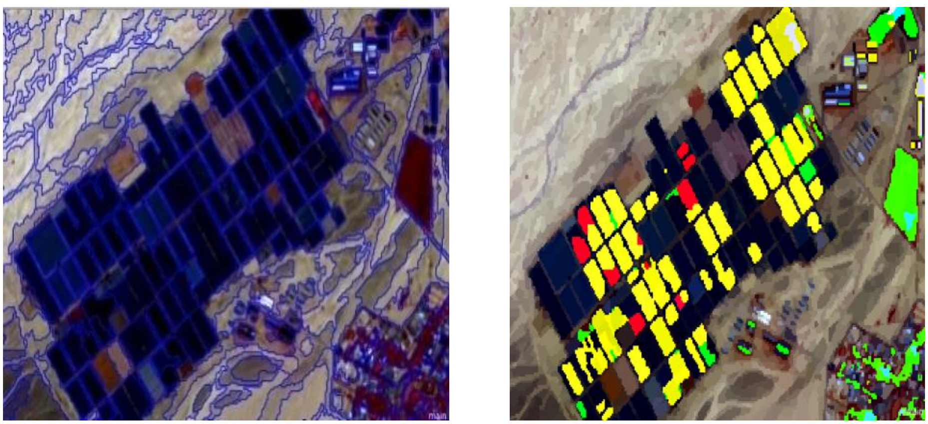
The object oriented classification is a multi-scale classification method performed in the software e-Cognition, which can work on radiometry, texture , shape etc parameters of image objects. Object oriented information extraction involves two critical steps - a) selection of optimum segmentation scale, b) development of an appropriate object-oriented information extraction strategy. Hierarchical Multi resolution image segmentation method is performed assuring homogeneity of concerning polygon properties, with the emphasis on aspects such as color or shape in comparison to compactness. This is a combination of the spectral and shape properties in smoothness and compactness criterion. This algorithm is a bottom up region- merging technique starting with one-pixel objects and a local optimization procedure (Benz et al., 2004). Specific settings for different segmentation levels are shown below.

Table 2. Parameters at different segmentation levels (lower the value for shape, the higher the influence of spectral value).

Level	Scale factor	Shape	Compactness	No of Polygons	Seperation
I	90	0.6	0.5	2,66,171	0.076
II	75	0.9	0.5	2,34,996	0.046
III	10	0.9	0.5	44,31,044	41.191

Image segmentation creates different size of continuous homogeneous objects as different features existing in study area have different sizes. The quality of the final classification definitions is linked directly to the quality of the segmentation and the quality of the classifier. Image objects are extracted from the image in a number of hierarchical segmentation levels, and each subsequent level yields image objects of a larger average size by combining objects from a level below. Scale parameter 10 creates smallest objects whereas scale parameter 90 create objects with large size terrain components. Object segments are identified to define the classes in a semi-automated way. Radiometric layer values of objects are analyzed while selecting training sets object class after visual inspection. Nearest neighborhood classification is used for classification.

Figure 5a and b. Examples of Object Segments and classification output with scale parameter 10 (Study area A).



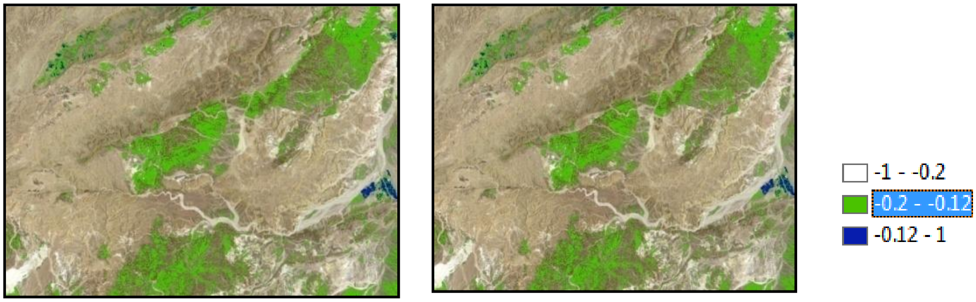


Figure 6. NDVI Image

The NDVI value for entire study area is very low and irrigated crops shows an NDVI value within the range of - 0.2 to -0.12 (Fig-6). Clastic soil types also fall in the same category as vegetation indicate that it has higher NIR reflectance component.

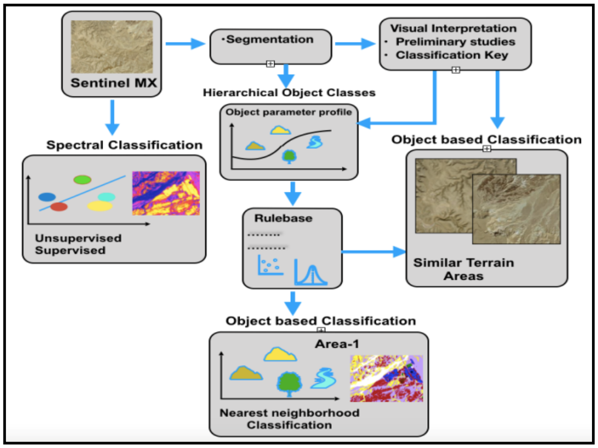


Figure 7. Flowchart describing the methodology followed.

Results and Observations

The results of the pixel based and the object-oriented classification of the images are compared using few test areas randomly over the image as well as with ground knowledge.
The FCC image of study area and corresponding photographs depict different terrain/ land use components.
The classification of desert plateau - and desert plateau with loess becomes slightly difficult as they are represented by medium reflectance, low NDVI and amorphous shape image objects. Study area A is an extreme rocky arid area devoid of vegetation and water. As there is not much difference in spectral radiometry of rocky desert areas and highland with losses in different thickness in pixel based classification, lots of pixels change their classes depending on the classification method. Clastic desert pavement, Desert Plateau and Desert plateau with loess, are the classes where this trend is seen maximum. In the object-based classification, all pixels that belong to one GIS object are grouped together. Therefore the objects belonging to a particular class are classified ignoring suppressible internal small variations. Object based classifications have profoundly less salt and pepper effect as the

classification is performed on objects instead of individual pixels. Therefore it drastically reduces a huge time consuming post-processing component. Because of medium resolution of the data, settlements like hamlets and Bedouin villages couldn't be detected as homogeneous areas but they are split into different lands classes depending on what the pixels are actually representing (bigger objects). Irrigated agricultural land and small undulations with clastic layers in Maktesh Raman are misclassified as water in all the classification because of their higher NIR component and smoothness. On the other hand sparse thorny vegetation/ grass on riverbed are categorized as desert component in all the classifications because of their low reflection in NIR band. Outputs of Object based methods are much simpler to perceive than pixel based methods. This is an important component for using the outputs for practical and operational purposes.

The rule sets have been saved to implement object based classification using the same parameters for terrain / land-use feature extraction with similar terrain types belonging to a different area or country. In present study the rule-sets of Area-A is implemented on a sentinel image of a bigger area at Egypt. The output is compared by visual assessment from the perspective of defence operations in unfamiliar terrain at different locations. The results indicate that classification results do not differ considerably. This may be due to the similarity of the terrain types/ land use. The implementation was found to be accurate for all classes except a few areas. However if there are any training bias in the principal image, that may get propagated for other areas also. The exercise demonstrates the rapid applicability of object based classification on target images for parameters that may be set using previously designed rules. It is found that object-based classification combines the advantages of both, visual interpretation and pixel-based classification.

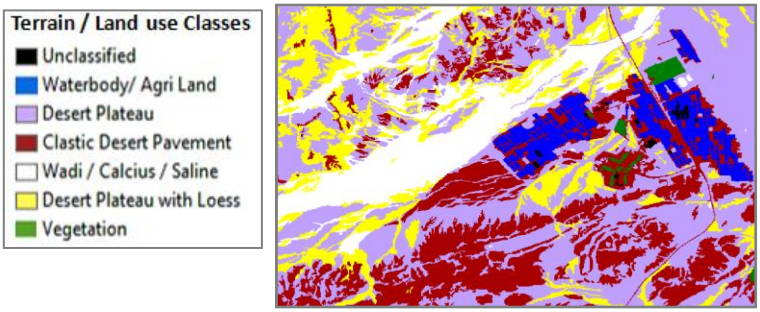


Figure 8. Output Objects class

Defence Applications

Remote sensing image analysis as well as derived products/outputs supporting information extraction are prime inputs for different defence applications. It can fulfill the requirements of the urgently needed information as well as requirements what can wait for longer preparatory time. This distinction is usually made on the basis of procurable. 3D Visualization methods. These requirements are getting translated in the form of urgent and fast information about terrain in a timely manner as well as detail terrain analysis.

Remote sensing and Geospatial systems allow rapid information land feature generation/ extraction using Object based Image classification method with automation in extraction. Covers and concealment and mobility maps are some of the important applications which required updated land feature information for a large area within a short time. Suitability studies products are generated and shown with a map indicating artillery positions. As certain areas acts as a vantage point for artillery positions while some other areas are marginal for battery fire positions, this kind of product act as a ready reference as well as reduces time when like indicating positions for suitable artillery sites below (Figure 9)..

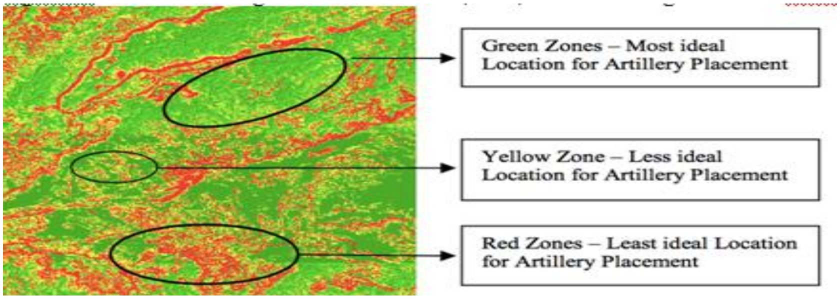


Figure 9. Site Suitability for Artillery placement.

It can also show areas concealed from known artillery sites and help in planning safe areas for shoot-and-scoot missions (Figure 9).Object based image analysis with high resolution data is useful to assess canopy cover for cover & concealment maps. A 3D terrain visualization with draped output land-use indicating terrain details and artillery positions.

Conclusion

The presented study has experimented with the objective of - a) to categorize terrain/ land use features in large regions in a very less time and resources which can be useful for practical purposes. b) development of a transferable methodology to implement for other areas. The outcome results are very encouraging using sentinel datasets. Object oriented approach for downsizing data is very useful as the data volume for large area is a hindrance to be handled by standard hardware equipment and current limits of the software. A few of misclassification area happens at spectral similar image area and the boundaries of different land cover types. The uses of additional data with object based classification will improve the classification accuracy. It enables immense opportunities for an automatic/ semiautomatic analysis of objects and land use/ terrain classification. More experiments are required to combine object based classification approach with knowledge base to be implemented on more number of areas to fulfill operational needs.

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