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Feature Extraction in an Aerial Photography of Gimnyeong Sand Dune Area by Texture Filtering

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항공사진의 질감 분석을 통한 김녕사구지역의 지형지물 추출

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Abstract : Earlier research works focused on the seasonal patterns and bio-geochemical processes in sand dunes, and the satellite data and aerial photographs have been used only as a backdrop or for the multi-temporal delineation of sand dune area. In order to find the optimal way to extract features' characteristics, Gimnyeong sand dune area was selected as a study site. Field works have been carried out three times to collect ground control points and sand samples for laboratory analyses. The texture of sand dune is classified as fine sand, which has been derived from shell fragments. The sand dune penetrated into the island from northwest to southeast direction. An aerial photograph was re-sampled into one-meter resolution and rectified with software including Erdas Imagine and ENVI. Sub-scenes were chosen as samples for sand dune, urban area and rural area. K-group non-parametric analysis had been done for the geometric and spectral values of enclosed texture patches. Urban areas proved to have significant smaller patches than the others.

요약 : 국내에서 해안사구의 생성과정 및 생물지화학적 특성에 대한 연구가 누적되어 왔지만 원격탐사방법을 이용한 분석은 범위를 파악하기 위한 수준으로 시각적 분석을 수행한 것이 대부분이다. 사구지역 범위 추출을 위한 적합한 질감분석방법을 찾아보기 위하여 제주도의 김녕사구지역을 대상으로 영상분석, 야외조사 및 통계분석을 실시하였다. 제주도 사구는 내륙으로 깊숙이 발달하고 있으며 현무암 돌담의 색채와 대비되어 단순 영상분류 분석보다는 질감분석을 적용할 경우 뚜렷한 범위를 도출할 수 있었다. 영상은 전처리 과정 이후에 Erdas Imagine과 ENVI 소프트웨어를 사용하였으며, 분산분석과 히스토그램 분석, 형태적 특성과 질감의 최고값에 대한 비모수 비교분석을 수행하였다. 도시지역은 농촌지역과 사구지역에 비해 질감의 변화가 폐합된 작은 폴리곤 형태를 나타내었으며, 사구지역은 도시지역과 유사한 높은 질감 변화값을 갖는다는 공통점을 갖는 반면에 폐합된 폴리곤의 크기는 농촌지역과 유사한 형태를 보여주는 이중적 특성을 보유하고 있었다. 하이패스필터적용 이후 생성된 사구지역의 폴리곤의 장축과 장축에 대한 단축의 비는 도시지역과 농촌지역에 비해 유의미하게 큰 것으로 나타났으며, 하이패스필터와 동일성 필터를 적용한 사례가 가장 효과적으로 도심지와 사구지역을 구별할 수 있었다.

주요어 : 사구, 제주도 김녕, 질감분석, 영상처리

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1. Introduction

The study site is located on the northeastern part of Jeju Island (Fig, 1). There are several sand dunes in Jeju Islands. On the northeastern part of Jeju, the sand dune penetrated into the island from northwest to southeast with diagonal direction due to the north-easterly winds in the winter season. The sand dune is 12km long and 4km wide. Sands of shell fragments cover the lowlands between lava flows (Fig.2).

Sand dunes have drawn a relatively great attention among the coastal landforms in these days (Seo, 2001; Kahng, 2003; Munyikwa, K. *et al.*, 2004; 2005; Park *et al.*, 2004). Earlier research works which used remotely-sensed data, however, focus on the seasonal patterns and bio-geochemical process in sand dunes; the satellite data and aerial photos have been used only as a backdrop or for the multi-temporal delineation of sand dune area by simple digitizing. In order to find the best way to extract features' characteristics including sand dunes, urban building and patches in rural areas, Gimnyeong sand dune area was selected as a study site (Fig.1). Field works have been carried out three times to collect ground control points and to sample sand for physical and chemical analyses. The results from the physico-chemical analysis have already been published (Park *et al.*, 2004). The texture of sand dune is classified as fine sand, which is supposed to have been derived from shell fragments.

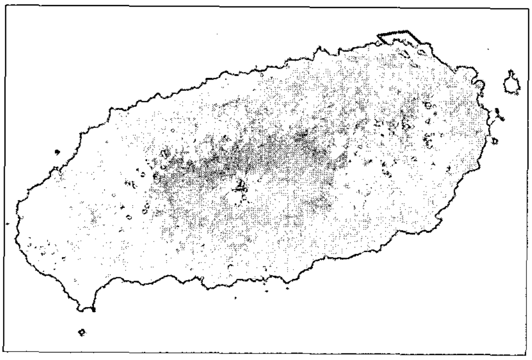

Figure 1. Image of Jeju Island and study area

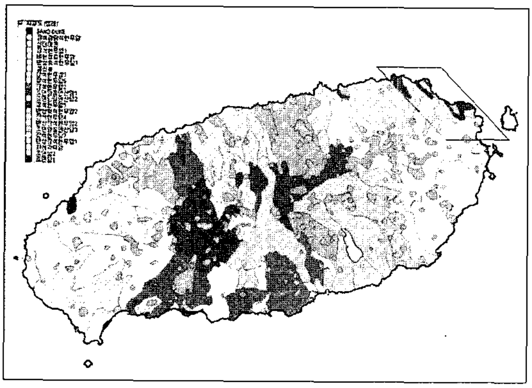

Figure 2. Geological map of the Jeju Island and study area

Previous studies using satellite images or aerial photographs focus on making mosaics of multi-temporal images, visual analysis or path analysis of sand movement. Levin and Ben-Dor (2003), for example, assessed a temporal changes in the stabilization process along the coastal dunes of Israel using a series of 23 aerial photographs taken over the period 1944~1999. The stabilization rate was then quantified using a specially developed method for the calculation of sand dune movement and by the calibration of the gray-scale images into vegetation cover maps. Other scientists did the similar works around the world including Arbogast *et al.* (2002), Kutiel *et al.* (2004), Lin *et al.* (1996). In Korea, Cho *et al.* (2001) reconstructed coastlines around the Hampyung Bay by using aerial photographs.

Al-Dabi *et al.* (1997), however, analyzed satellite images in north-western Kuwait and revealed a prominent north-west/south-east-trending sand dune corridor. They delineated the main geomorphic features of the dune field by analyzing a set of multi-date Landsat Thematic Mapper (TM) images (from both before and after the Gulf War) to monitor temporal and spatial changes in the sand dune patterns. Image-enhancement techniques, including edge enhancement filters and contrast stretches, were utilized to delineate the sand dune field.

Pease *et al.* (1999) also used sand samples and Landsat images to characterize the spatial distribution of sand mineralogy, and to evaluate potential sources and transport pathways of sediment in the Wahiba Sand Sea in Oman. Landsat TM data were used in the geomorphic interpretation of a desert, aeolian environment to distinguish the mineralogy found in the Wahiba area, and in extending the identification of sand mineralogy beyond the point-specific grid produced from field sampling. They concluded from the field and Landsat TM data that the upper Wahiba is comprised of well-mixed carbonate and quartz sand with some areas of significant mafic content.

Texture analysis is rather an approach to discern characteristics of a subject from the relationships among the proximate pixels than a reflection values on a pixel-by-pixel basis. Texture analysis has been developed to derive crown morphology and key values of trees (Hudak and Wessman, 1998; Kayitakire and Defourny, 2006). Radar images of Mexico were analyzed with texture filtering methods to extract wells and temporary shelters of refugees, in order to estimate the size of refugee population (Baker *et al.*, 2001). Congalton(1991) and Harris(1995) reported that the additional layer of texture analyses contributed to increase the land classification accuracy. Especially SAR (Synthetic Aperture Radar) images with dissimilarity, entropy, correlation filter applied have good

Table 1. Materials and Methods for Image Analysis for Coastal Landforms Including sand dunes

authors	scale of study areas	images to use and methods
Al-Dabi *et al.* (1197)	Landsat 1 sheet	Landsat TM Grid method - sand dune area percentage ranking per gird temporal comparison for 3 different periods
Pease *et al.*(1999)	Landsat 1 sheet	Landsat TM band combination & field works clustering method
Levin *et al.*(2003)	4 sheets of aerial photographs 6 different period total 23 sheet of aerial photography	aerial photographs digitizing change detection accmulation comparison vegetation process, disturbance, human constraints mapping sand dune front line changes extraction
Kutiel *et al.*(2004)	13km^2 sand dune 1 sheet of aerial photo five period	normalization process 16 landscape pattern classification by naked eye digitizing shannon index calculation based on field work model setting for the future
Arbogast *et al.*(2002)	Michigan Lake area 1.6km	linear extraction
Lin *et al.*(1996)	40km southern Taiwan	Land classification map based on aerial photographs
Cho *et al.*(2001)	Hampyung bay	aerial photograph, DLTanalysis

summarizing results with less redundancy of data, especially when the delta value which means pixel distance and theta value which means orientation of delta value were applied to whole scene.

The extraction of objects based on texture can be classified into four groups such as statistical method, structural method, model-based method and transformation method (Bharati *et al.* 2004, Kiema 2003). One of the typical statistical methods is gray level co-occurrence matrix which extracts the texture characteristics by secondary statistics of image histogram. Structural method is to calculate the gap between given texture and theoretical texture with specific direction of texture. Model-based texture method includes Markov random field method, fractal model and laying weight of specific pixel (Smith, 2002). Finally, transformation texture methods include the Fourier transformation and multi-directional principle component analysis or Gabot filter or wavelet filter. Here we chose the statistical method in the analysis of study area.

2. Methodology and Statistical Results

An aerial photo taken in 1979 was re-sampled into one-meter resolution deliberately and

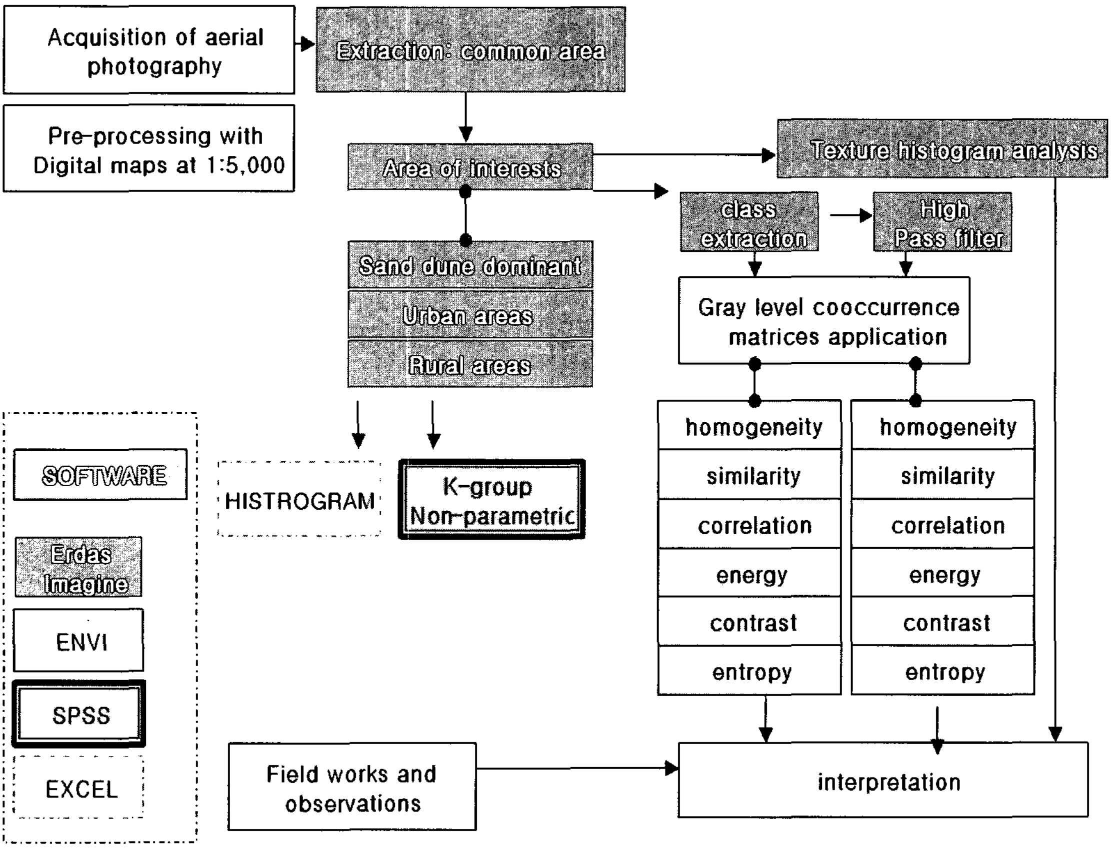

Figure 3. Work flow chart for the feature extraction.

rectified by nearest neighborhood re-sampling method with commercial software such as Erdas Imagine 8.6 and ENVI. Work flow diagram for the study can be summarized as figure 3. The reason for the re-sampling is to simulate the images which will come from the satellite available in the end of 2006. Sub-scenes were chosen as samples for sand dune, urban area and rural area. Variance values of each sub-scene were analyzed and plotted with pseudo-color slicing and histograms of the variance values were plotted after converting texture values into ASCII file format. K-group non-parametric analysis has been applied for the geometric and spectral values of enclosed texture patches.

Image texture, defined as a function of the spatial variation in pixel intensities (gray values), is proven to be useful in a variety of application and has been a subject of intense study by many researchers. One immediate application of image texture is the recognition of image regions such as dune fields using texture properties.

1) Comparison of texture analysis

The result from simple texture analysis can be summarized as follows.

The results from the texture analysis have been expressed in pseudo-color steps. Covariance within the urban area exhibits small but steep spatial trend and pattern of small closed eclipse or partly closed pattern. In sand dune area and rural area, patches derived from the traditional basalt fences in Jeju exhibit larger patches and open parabolic and other patterns are also shown simultaneously. In case of sand dune area in figure 4, steep changes in texture are shown, especially the area where sand dune spread out through basalt fence, except north western part where volcanic rocks

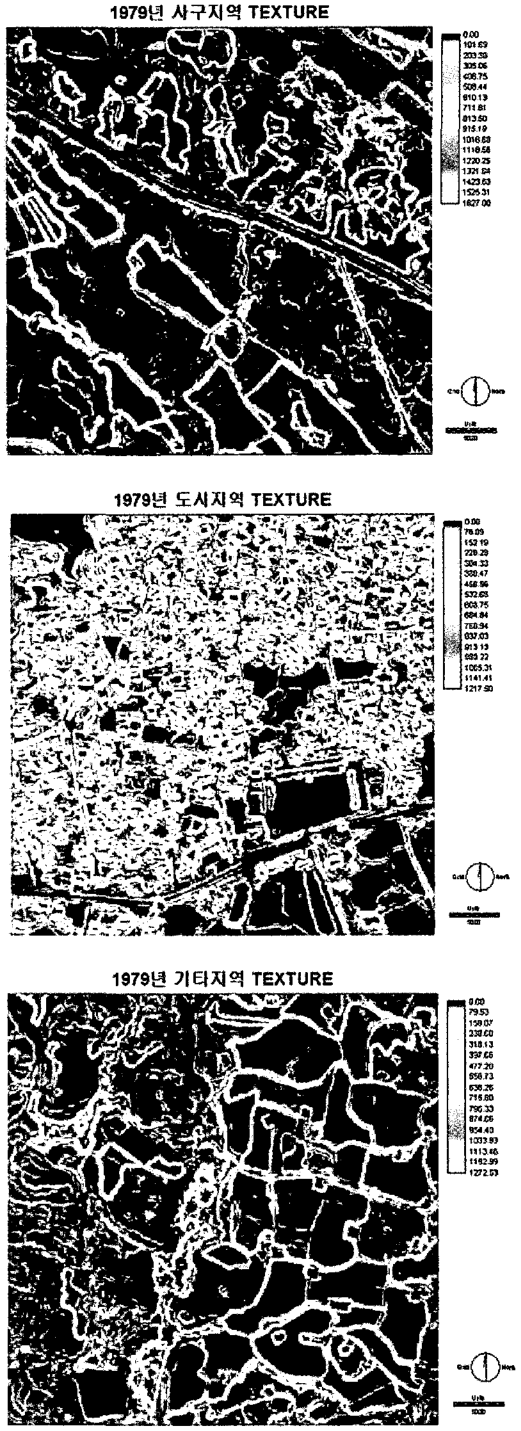

Figure 4. The result of texture analysis of sand dune areas rock-ffenced (upper left), urban areas (upper right), rural areas (boottom) in aerial photography in 1979

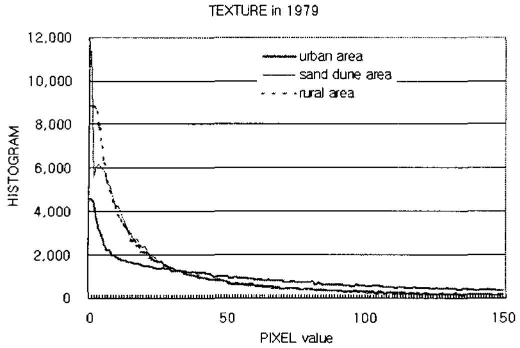

Figure 5. The distribution of texture pixel values of rura areas (dotted lines), sand dune areas rock-fenced (thin solid line), urban areas (thick solid line) in aerial photography in 1979

distributed in the form of wedge

The histogram of subset variances are shown in figure 5. Urban area exhibits higher variance and the change of texture is higher than sand dune area, as the change values larger than thirty five are relatively concentrated in urban area. On the contrary, sand dune area has higher histogram values on the range of less three, as sand dune shows continuous texture with little variance. The texture profile shows similar characteristics to urban area due to repetition of land use such as mandarin orange tree and agricultural patch, as well as continuous texture due to open land before land development.

Table 2. Ranking values of each class

	Ratio	Long Axis	Short Axis
kai square	11.784	10.452	1.836
degree of freedom	2	2	2
p values	0.003	0.005	0.339

2) Statistics

The characteristics of shape can be defined by many shape factors, such as long axis, short axis, and the ratio of short axis to long axis. We measured the basic three factors from polygons generated from high pass filter images and obtained the independent Kruskal-Wallis statistics, which is one of non-parametric statistics. Table 2 and 3 indicated that the long axes of polygons in

Table 3. The results form Kruskal-Wallis statistical test

	Area	N	Average Rank
Ratio	sand dune	12	25.33
	urban area	12	23
	rural area	14	11.5
	total	38	
long axis	sand dune	12	14.13
	urban area	12	16.08
	rural area	14	27.04
	total	38	
short axis	sand dune	12	16.42
	urban area	12	29.33
	rural area	14	22.29
	total	38	

urban area are significantly ranked lower than those in rural and sand dune area (p=0.003 degree of freedom=2).

The short axes are not significantly different among the three areas (p=0.339), but the ratio of short axis to long axis differed significantly (p=0.005).

3) Comparison of texture analysis: each area

High pass filter is designed to ignore trivial variance by multiplying higher values to nine cells or sixteen cells or twenty five cells. The distortion problem from the high pass filter was pointed out by Goodchild (1993). Here we also find the similar horizontal and vertical noise on the results of texture analysis which does not have special meanings.

The strips on the lower images in figure 6 were also observed. We used 3X3 windows for all the three subset, and then open land has the same texture values in both rural area and sand dune area. Simple naked eye inspection for texture value does not allow us to distinguish sand dune area from the other land uses except the linear pattern of long axis of sand dune area.

Homomorphic filter was then applied to urban area and compared to that of high pass-filter (figure 7 and figure 8). The left upper part show the similar reflectance of buildings, homomorphic filter is known as the best filter for extraction of building (Zhang, 2004; Anys, 1994). On the contrary, dissimilarity filter is good for the extraction of the buildings among urban features such as roads and buildings. Zhang(2004)'s research showed correlation filter is significantly meaningful for the extraction of building, this study, however, shows different result, in which correlation filter exaggerated the road pattern rather than buildings.

On the contrary, building can be shown when

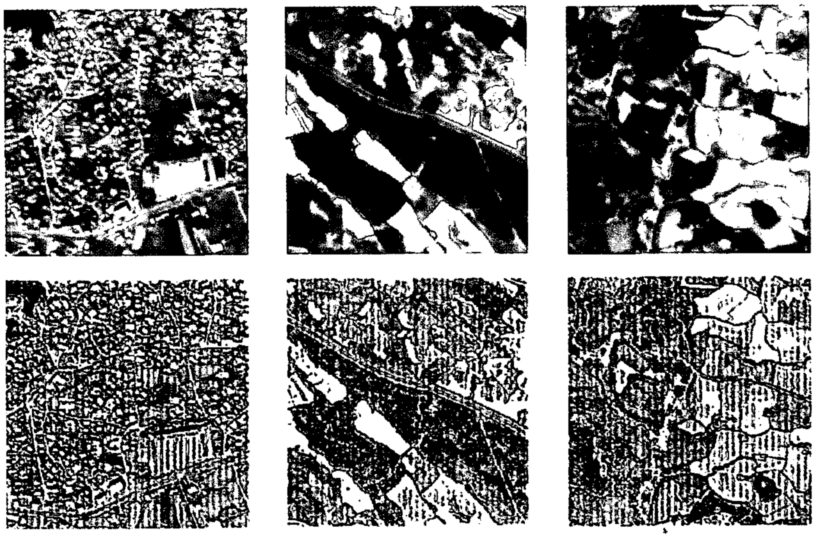

Figure 6. Subset images and high pass filtered images

urban area (left), sand dune rock fenced (middle), rural areas (right) : raw image (upper)
urban area (left), sand dune rock fenced (middle), rural areas(right) : high pass filtered (bottom)

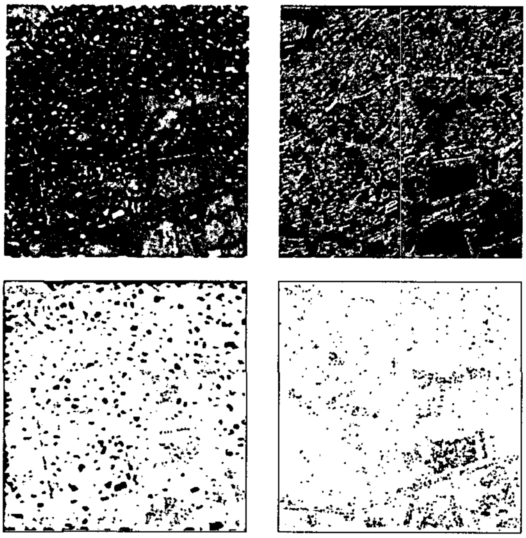

Figure 7. Urban areas

GLCM application on the subset of urban area homogeneity (upper left), dissimilarity (upper right), entropy (bottom left), correlation (bottom right).

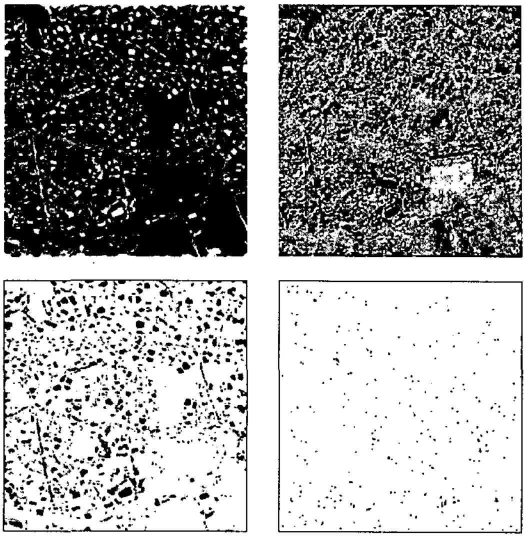

Figure 8. urban areas

GLCM Application on the Subset of High-Pass Filtered Urban Area homogeneity (upper left), dissimilarity (upper right) entropy (bottom left), correlation (bottom right).

high pass filtered images was refiltered by homomorphic filter and linear pattern was shown clearly when the pattern had not been observed on homogeneity filtered image. Homomorphic filtered image after correlation filter did not show the extraction of buildings and roads that was shown on correlation filtered image.

Entropy filter has higher values when neighboring pixel has similar values. So individual building extraction can be done more effectively by using entropy filter. Later point data of interests can be connected to entropy filtered image. Dissimilarity filer has the same effect as edge filter without noticeable characteristics.

Figure 9 showed the image of homomorphic filter. The subset was covered not only by the sand dunes but also by the neighboring volcanic rocks penetrated to northwestern part. The area covered by sands proved to have values of one as homogeneity values. So homogeneity filter is good for extraction of sand dune area. Dissimilarity values, on the contrary, showed zero values for the sand dune area, which means dissimilarity value is also a good filter for extraction of certain object which has continuous values. Correlation filtered image showed salt and pepper type images with no meaningful context.

The subset of rural area was taken to make sure the areas should include some open land in order to compare sand dune areas which may show the characteristic of open land. The reflectance value of raw image show higher values in rural area than sand dune area, but figure 10 showed GLGM applied images showed more irregular patterns than those in sand dune area which have northwest-southeast linear pattern.

Especially patches surrounded by basalt fence have different land use, whether vegetated or non-vegetated. The texture values of sand dune area have also some inner variance. The phenomena observed in raw image and high pass filtered image were not enhanced, but the spatial connection was enhanced. So the open land was apparently shown, the other land usages were shown with a little difference.

3. Conclusion

Sand dunes of concern in this study are characterized by their deep penetration into the land, therefore textural analysis is proved to be very effective to delineate dune area due to the color of basalt walls surrounding plots. Field works and physico-chemical analysis found that dune sands are made of shell fragments and very fine sands.

Instead of using aerial photos as it is to delineate dune area, we degraded aerial photos to KOMPSAT 2 level deliberately to test the applicability of satellite images in the future. In this respect, it may be possible that we derived slightly different results out of aerial photo analysis. The Kruskal-Wallis statistics of texture analyses, however, showed significant difference in the polygons of sand dune area, rural area and urban area (long axis, $p=0.003$; ratio of short axis to long axis, $p=0.005$). Homogeneity filter and dissimilarity filter were proven to be very effective one to distinguish sand dune area from both rural and urban area.

Time sequential analysis of aerial photos for the region is necessary to understand both the stabilization and expansion processes of dune area and the study of seasonal variations are also necessary to understand the dune forming process and enhance the effectiveness of texture analysis. Future studies could solve the aforementioned problems.

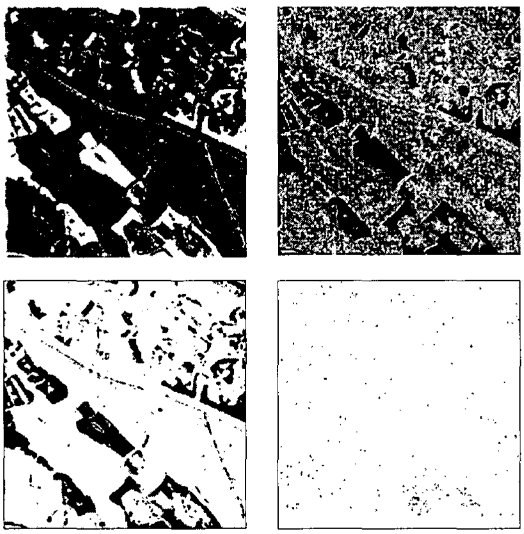

Figure 9. Sand Dune Areas

GLCM application on the subset of urban area homogeneity (upper left), dissimilarity (upper right), entropy (middle left), correlation (middle right).

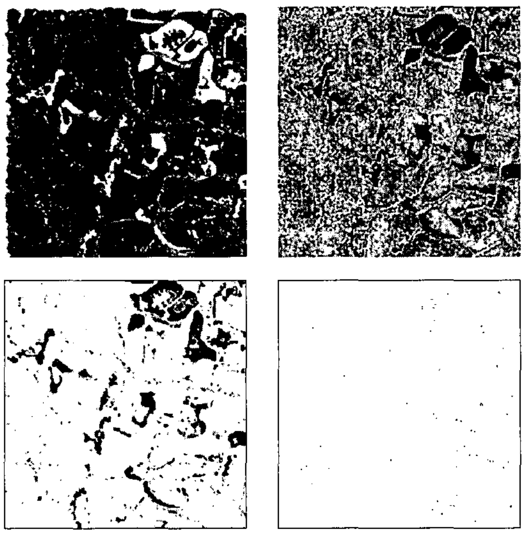

Figure 10. Rural Areas

GLCM application on the subset of urban area homogeneity (upper left), dissimilarity(upper right), entropy (middle left), correlation (middle right).

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