THE ABILITY OF DIFFERENT MULTISPECTRAL IMAGES FOR SPATIAL EXTENT MAPPING OF LAKES AND COASTAL WETLANDS

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ABSTRACT:

Identification of primary classes and sub classes of open water bodies and wetlands using remote sensing data is very important for different purposes. Because of the mixture of water and vegetation in wetlands, the spectral properties of wetlands are a complex mixture of the two. Therefore, when the different wetlands are located near or around the lakes (coastal wetlands), spectral discrimination of the lake is rather difficult. Hirmand, Sabury and Poozak lakes located in the boundary region between Iran and Afghanistan have high temporal plant coverage changes. There are a number of wetlands around these lakes especially around the Puzak which is located in Afghanistan.

In this study, the performance of different resolutions of multi spectral images including Landsat-TM (28.5 m), NOAA-AVHRR-LAC (1.1 km) and GAC (4 km) images for mapping of lakes and coastal wetlands has been studied.

The feature extraction methods consist of supervised classification methods (parallelepiped, minimum distance, Mahalanobis distance and maximum likelihood classification) using training data of open water bodies and land regions (with or without vegetation) without any training data of wetlands, unsupervised classification (Heckbert quatization algorithm), Normalized Difference Water Index (NDWI), Normalized Difference Vegetation Index (NDVI), Wetness Index, Principal Components Analysis (PCA) ,and Thresholding methods on different bands.

In this paper, false color composite (FCC) and NDVI maps of TM-image have been used as a reference for comparison of the capabilities of different methods.

The results showed that without any training data of coastal wetlands, the Landsat-TM images are capable of mapping the lakes and coastal wetlands. The AVHRR-LAC images are useful for identification of the lakes and for detection of the coastal wetlands and its pattern, but not capable of accurate estimation of the wetlands area. The AVHRR-GAC images only are useful for identification and area estimation of lakes.

1. INTRODUCTION

Separation of primary classes (e.g. water bodies) using remote sensing data is important for area measurement of different classes and for studying the existing subclasses within the primary classes. Because of the very low reflection of water in infrared portion of the spectrum (0.7-3μm) (Engman and Gurney, 1991), water bodies appear dark in gray scaled images and can be easily separated of surrounding vegetation and soils (Swain and Davis, 1978). Therefore the appropriate bands of different sensors for identification of open water region are band 7 of Landsat-MSS; Band 4 of Landsat-TM; band 3 of SPOT-HRV and band 2 of NOAA-AVHRR (Kite and Pietroniro, 2000). Landsat-MSS or TM may easily measure the lakes greater than 100 km^2 with less than 1% error (Harris, 1994). The remote sensing was very useful and suitable for this study because of its remoteness, size, and lack of accessibility.

Many different image processing methods have been used for separation of water bodies of remote sensed data, such as thresholding method (e.g. Lascassies et al., 1994; Mouchot et al., 1991), supervised statistical classification algorithms (e.g. Benediktsson et al., 1990; Key et al., 1990), unsupervised classification algorithm (clustering method)(e.g. Tadesse et al., 1991), Principal Component Analysis (e. g. Yongnian et al., 2001).

Wetland is one of the most important mass productive ecosystems. Therefore, detection and monitoring of their changes is important. Under the different constraints (such as restricted access to marshes and limited availability to data), the interpretation of digital satellite imagery is a suitable alternative (Brasington, 2001). The remote sensing data is the most important tools for the monitoring of wetland (Wang et al., 1998) and some researches have demonstrated the potential of remote sensing data for multi temporal characterization of large wetlands (e.g. Shima et al., 1976 and Jensen et al., 1995) and extraction of detailed information of wetlands such as wetland size, shape, type and extent (Jollineau and Howarth, 2002). Klemas et al. (1993) pointed out that using of remote sensing data for wetland monitoring is a time and cost saving method.

Reimold and Linthrust (1975) summarized contemporary remote sensing methodology and its applications in wetlands using photography and multiband imagery. They showed the ability of remote sensing data for determination of the location and boundary of wetlands. The U.S. Geological Survey has showed the ability of remote sensing and photogrammetric techniques for mapping and delineating coastal wetlands during aresearch project in the vicinity of Sapelo, Georgia (McEwen et al., 1976). Jensen et al. (1986) showed that the Landsat-MSS data is useful for mapping the area extent of wetlands. NERAC (1993) has presented a bibliography of citation on remote sensing of wetlands and swamps. Rundquist et al. (2001) have

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provided a brief review on the wetland identification, classification, biomass measurement and change detection using remote sensing. Brasington (2001) used the Landsat-driven NDVI and supervised classification methods for multi temporal classification of marshlands in south of Iraq. In this research, the regions of marshlands were separated on Landsat images before the classification. Jollineau and Howarth (2002) used IKONOS and air photo interpretation and supervised and unsupervised classification techniques for extraction and classification of wetland and shallow open water in South-Central Ontario. Iyer and Mohan (2002) used the supervised statistical classification approach for separation of water bodies, marshy land and other phenomenon of IRS data for Mumbai area.

However, because of the contrast between water and vegetation, the separation of water bodies and vegetation, using remote sensing data is easier than the separation of water bodies and coastal wetlands, because of the spectral similarity between water bodies and wetlands (Kite and Pietroniro, 2000).

In this study, several image processing methods for identification of lakes and coastal wetlands using different resolution of multi spectral images have been tested. Also the ability of each resolution for detection and identification of lakes and coastal wetlands has been evaluated.

The image processing methods, which will be used in this study are introduced in section 2. In sections 3 and 4, some explanations about the case study and remote sensed data will be presented. In section 5, different image processing methods and their combinations , which have been exerted to different images will be explained. The results of detection and identification of lakes and wetlands by different images and performance of different image processing methods will be presented in section 6. Finally, some conclusions of this paper will be presented in section 7.

According to the limitations of enough space, only a brief explanations have been presented in different sections of this paper. For comprehensive information of different sections of this paper refer to the Coastal-Wetlands report in the following address:

http://ewrc.sharif.edu/publication/paper.asp

2. ALTERNATIVE PROCESSING METHODS

The image processing methods which have been used in this study are consist of supervised and unsupervised classification methods, Principal Component Analysis, NDVI, NDWI,Wetness index and threshold method. The supervised classification methods are consist of Maximum Likelihood, Mahalanobis Distance, Minimum Distance and Parallelepiped. The unsupervised classification method (clustering) that is used in this study is Heckbert quantization algorithm (Heckbert, 1982). For more information about these methods, refer to Richards (1993) and Mather (1987).

3. STUDY AREA

The study region is consists of Hirmand, Puzak and Sabury lakes, which have been located in the southeastern region of Iran ($30^o,20^{'}-31^o,42^{'}$ E and $60^o,45^{'}-62^o,10^{'}$ N). These lakes are located in the boundary region of Iran and Afghanistan (Figure 1). When these lakes are connected together, the area, volume, average depth, maximum depth, and evaporation are approximately 3600 (km^2), 4300 (milion m^3), 1.2 (m), 4.1 (m) and 4.5 (m/year), respectively. There are some wetlands in the coastal regions of these lakes (Figure 2).

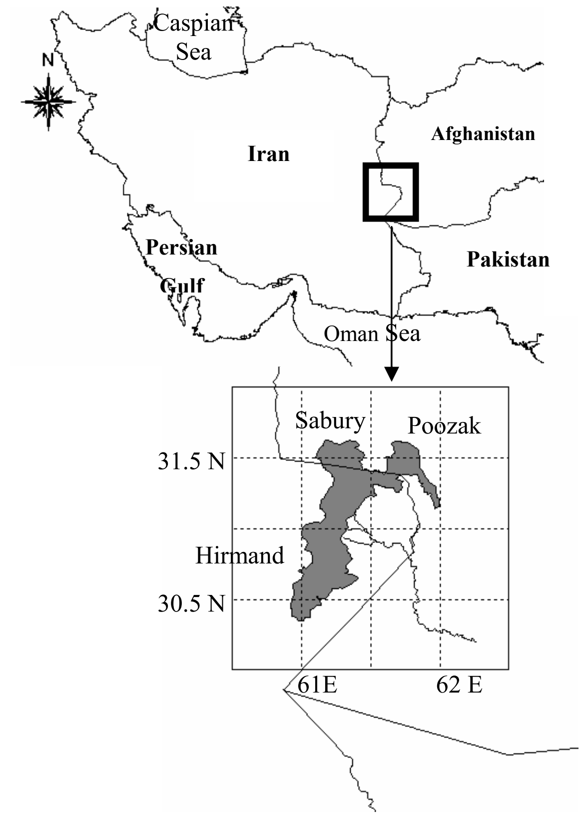

Figure 1. Study area and location of Hirmand, Sabury and Poozak lakes

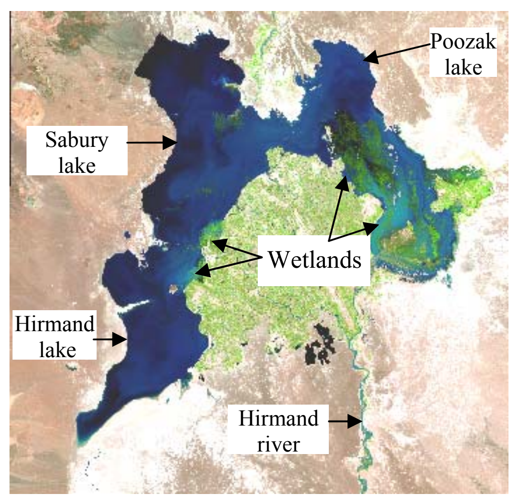

Figure 2. False color composite (FCC:543) map of the study area generated by Landsat-TM (15 April 1998)

These wetlands are registered as Ramsar sites. In these wetlands, the water body is covered by vegetation. This region is an area of major national and international importance because, they are the largest fresh water wetland ecosystem in the desert region between Iran and Afghanistan that controls the microclimate of the region and once it is covered by water, reduces sand wind frequency and aeolian erosion considerably and makes the environment suitable for migrating birds and wild life habitat and aesthetic amenities. After the 1999-2003 drought the lakes became completely dried. The climate of this region is arid and annual precipitation is approximately 55 mm. Snowmelt runoff of the Hirmand basin located in Afghanistan and Hirmand river provides water for the Poozak, Sabury and Hirmand lakes (Figure 2).

4. REMOTE SENSING DATA

The region of study is covered by two frames of Landsat-TM data (path/row: 157/38 and 157/39), where the size of each pixel of this data is approximately 28.5×28.5 m. The frames of April 15, 1998 were used for this study. False color composite map (FCC. 543) of the study area, generated by TM data has been shown in Figure 2. To have approximately concurrent TM and AVHRRimages, the NOAA-AVHRR images in local area coverage (LAC) format of April 18, 1998 and in global area coverage (GAC) format of April 15, April 17 and April 18, 1998, have been used in this study. The field of view of LAC and GAC format images are approximately 1.1 km and 4 km at nadir, respectively.

5. METHODOLOGY OF DATA PROCESSING

5.1 TM data:

Algorithm	Explanation
M1	Threshold of PC1, generated using bands 4, 5 and 6
M2	Threshold of PC1, generated using 7 bands
M4	Threshold of NDWI map
M5	Threshold of Wetness index map
M6	Threshold of band 4
M7	Threshold of band 5
M8	Threshold of band 6
M9	Combination of M6-M8
M10	Clustering using 30 classes
M11	Maximum likelihood classification
M12	Mahalanobis distance classification
M13	Minimum distance classification
M14	Parallelepiped classification

Table 1. Algorithms for separation of water bodies of TM data

First, mosaic of two frames of TM data were produced. Then, the false color composite map of the region was created and some training data were picked up of the open water bodies and land (with or without vegetation) regions, without any training data for wetlands. Then the different image processing methods have been exerted to TM image for separation of open water bodies and wetlands. Tables 1 and 2 shows these methods.

Algorithm	Explanation
M15	Combination of NDVI map (M3) with M12 and M4
M16	Combination of NDVI map (M3) with M12 and M5
M17	Combination of NDVI map (M3) with M11 and M4
M18	Combination of NDVI map (M3) with M11 and M5

Table 2. Algorithms for separation of wetlands of TM data

5.2 **AVHRR-LAC data**:

The methods, which have been used for separation of open water bodies and wetlands of AVHRR-LAC data have been presented in Tables 3 and 4.

Algorithm	Explanation
M1	Maximum likelihood classification
M2	Mahalanobis distance classification
M3	Minimum distance classification
M4	Parallelepiped classification
M5	Clustering method
M6	Threshold of NDVI map
M7	Threshold of band 3
M8	Threshold of PC1
M9	Threshold of band 2
M10	Combination of NDVI map and M7
M11	Combination of NDVI map and M8
M12	Combination of NDVI map and M9
M13	Combination of NDVI map and M1
M14	Combination of NDVI map and M2
M15	Combination of NDVI map and M3
M16	Combination of NDVI map and M4
M17	Combination of NDVI map and M5

Table 3. Algorithms for separation of water bodies of AVHRR-LAC and GAC images

Algorithm	Explanation
M18	Combination of M4 and NDVI map
M19	Combination of M3 and NDVI map
M20	Combination of M7 and NDVI map
M21	Combination of M8 and NDVI map

Table 4. Algorithms for separation of wetlands of AVHRR-LAC and GAC images

5.3 AVHRR-GAC data:

Similar to the LAC-image, some methods were performed on the GAC images (Tables 3 and 4).

6. RESULTS AND DISCUSSION

6.1 TM data:

The areas of water bodies, which have been extracted by different methods, are presented in Table 5.

Evaluation of different methods were based on visual interpretation of FCC (Figure 2) and NDVI map. For example, for open water bodies, the NDVI values should be high negative values. The results of visual interpretation showed that the thresholding method of principal components (M1 and M2), NDWI (M4), wetness index map (M5), band 5 (M7) and band 6 (M8) maps overestimate the area of open water bodies.

Method	M1	M2	M3	M4	M5	M6	M7
Area (Km^2)	4211	4248	___	4195	4286	3775	4124
Method	M8	M9	M10	M11	M12	M13	M14
Area (Km^2)	4150	3615	3930	3610	3589	4875	3654

Table 5. The area of water bodies, extracted by different methods using TM data.

In addition, these methods need to determine the threshold value which have high skewness and kurtesis histogram; however determination of the proper threshold can be difficult. The visual interpretation on the Maximum likelihood (M11), Mahalanobis distance (M12), and Parallelepiped (M14) classification methods showed that these methods are very useful for separation of open water bodies, and these methods cannot separate the water bodies with low vegetation coverage or mixed pixels. Therefore presumably, these methods somewhat underestimate the area of water bodies. Figure 3 shows the generated water body map, using the Maximum likelihood classification.

Figure 3. Water body map separated of TM image and generated by using maximum likelihood classification method.

Therefore for identification of the open water bodies, Maximum likelihood and Mahalanobis distance methods are the most appropriate methods (~ 3600 km^2). But the methods such as NDWI or wetness index separate the open water bodies, wetlands, mixed pixels and shallow water regions together. But the results of the combination of NDVI map and water maps generated by classification methods with wetness index (M16 and M18) for separation of wetlands, didn't have reasonable correspondence with that of the visual interpretation, but the combination with NDWI map (M15 and M17) showed very good results.

Figure 4 shows the different wetlands, which have been separated of TM data. The area of wetlands was estimated, approximately 240 km^2.

Figure 4. The wetlands, which are separated from TM image

6.2 AVHRR-LAC data

The results of the determination of the spatial extent of water bodies showed that some of these methods (Threshold of band 3 (M7) and PC 1 (M8), and Clustering (M5), Minimum distance (M3) and Parallelepiped classification (M4)), overestimate areas and give inaccurate patterns. The Mahalanobis distance (M2) and Maximum likelihood (M1) methods presented appropriate area estimation and not very good patterns. Threshold of band 2 showed a little appropriate area estimation and not very good patterns, but the threshold of NDVI (M1) method showed very good patterns and appropiate area estimation. Figure 5 shows the water body map separated of LAC image and generated using NDVI map. The pattern of water bodies, generated using the supervised classification methods, band 3 and PC 1 improved by combination of these methods with NDVI map (M13-M16 and M11-M12). Table 6 shows the areas of water bodies, which have been extracted using LAC image.

Method	Area (Km^2)	Method	Area (Km^2)
M1	3720	M10	3370
M2	3720	M11	3870
M3	4400	M12	3850
M4	4370	M13	3630
M5	5000	M14	3630
M6	3730	M15	3930
M7	4300	M16	3930
M8	4250	M17	4300
M9	3400	M18	_

Table 6. The areas of water bodies, extracted by different methods using AVHRR-LAC image.

The differences in the patterns of NDVI and water maps, generated using band 3, PC 1, Minimum distance and Parallelepiped classification methods; are due to the wetland regions. Table 7 shows the estimated area for wetlands by different methods. Comparison of estimated areas and patterns for wetlands by Landsat-TM image (240 km^2) and AVHRR-LAC image showed that the AVHRR-LAC images are able for

detection and pattern recognition of wetlands (Figure 6), but are unable for good area estimation of wetlands because of high error values(~55%).
The results of different methods are similar together (see Table 7), therefore all of these methods are useful for coastal wetland detection and mapping.

Figure 5. Water body map separated of LAC image and generated using NDVI map

Method	M18[a]	M19	M20	M21
Area (km^2)	410	420	390	370

Table 7. The estimated area for wetland regions using different methods and AVHRR-LAC images

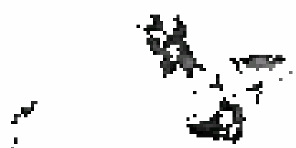

Figure 6. The wetlands, which are separated of AVHRR-LAC image

6.3 AVHRR-GAC data

Table 8 shows the results of water body area estimation by different methods, using April 17, 1998 image.
The open water body areas estimated using Maximum likelihood (M1), Mahalanobis distance (M2), band 2 (M9),and combination of these methods and NDVI map (M12, M13 and M14) result accurate approximation, while the Parallelepiped, Minimum distance classification, Clustering, and band 3 results overestimate the area of open water bodies. Figure 7 shows the water body map separated of GAC image and generated using Maximum likelihood classification method
Table 9 shows the results of area estimation of wetlands using GAC image. The results of Table 9 and pattern of extracted wetlands show that the GAC images are not capable of area estimation and pattern recognition of coastal wetlands.

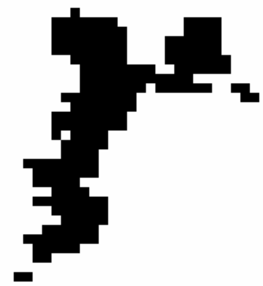

Figure 7. Water body map separated of AVHRR-GAC image and generated by using maximum likelihood classification method

Method	Area (Km^2)	Method	Area (Km^2)
M1	3620	M10	3740
M2	3580	M11	3920
M3	4450	M12	_
M4	4590	M13	3612
M5	4560	M14	3580
M6	3740	M15	3920
M7	4320	M16	4350
M8	_	M17	_
M9	3840		

Table 8. Estimated water body by different methods, using the AVHRR-GAC image of April 17, 1998.

Method	M18	M19	M20
Area (km^2)	_	416	400

Table 9. The estimated area for wetland regions using different methods, (GAC image: April 17, 1998)

7. CONCLUSIONS

The following conclusions are drawn, on the basis of image processing performed in this study:
1. According to visual interpretation of NDVI and FCC maps, among different studied processing methods, the Maximum likelihood and Mahalanobis distance classification methods are the most appropriate methods for the separation of open water bodies on TM image in the state of vicinity of coastal wetlands.
2. Using the TM data, some of the methods (e.g. NDWI and wetness indices) over estimate the open water body area.
3. Combination of generated water maps using NDWI and Maximum likelihood or Mahalanobis distance is a useful way for identification of wetlands.
4. In comparison of different image processing methods using AVHRR-LAC and GAC images, Maximum likelihood classification and Mahalanobis distance classification methods

and thresholding of NDVI map and band 2 showed accurate areas and patterns for lakes (open water bodies).

5. In LAC image, combination of generated water maps using band 3, first principal component, minimum distance and Parallelepiped classification with NDVI map, is useful for wetlands detection and mapping, but is not useful for area estimation.

6. The GAC Images are not useful for detection of the coastal wetlands.

7. In all of these methods which were used for estimation of open water body area and pattern using different multi spectral images, estimation can be improved their estimations when combined with NDVI map.

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