INFORMATION CONTENT ANALYSIS OF LANDSAT-8 OLI DATA FOR WATER RESOURCES MANAGEMENT

Ballu Harish1, A. Nikil saii1, L.Ravi2,Dr.R.S Dwiwedi2
1. Lecturer, Department of Centre for Spatial Information Technology, JNTUH-IST
1. Student , Department of Centre for Spatial Information Technology, JNTUH-IST
2. Ph.D scholar Department of Centre for Spatial Information Technology, JNTUH-IST
2.Academic Advisor Department of Centre for Spatial Information Technology, JNTUH-IST

ABSTRACT

Study focus:

Remote sensing sensors operating in the optical region of the spectrum capture reflected & / or emitted electromagnetic radiation from the object /features, which facilitates their identification / detection . Beginning with a few spectral bands in early 1970s, for example, in Landsat Multispectral sensor now the user community has access to remote sensing images with hundreds of spectral bands, viz. Hyperion image with 232 spectral bands. The challenges faced by image analyst is how to minimize the data analysis time without sacrificing the information content of remote sensing images. The information present in remote sensing imagery depends to a large extent on various factors like spatial, radiometric resolutions and amount of noise present in the imagery. It points to minimizing the number of spectral bands by using appropriate image processing techniques into a few spectral vectors/ indices. Towards this end, several spectral indices/ spectral transformation approaches, namely image entropy, Principal Component analysis , Optimum Index Factors ,etc. have been developed and used for inventory and monitoring of water resources, extent, distribution and temporal behaviour of water bodies. The focus of the article is on selection of spectral features using the image processing tools available in ERDAS / IMAGINE which are indicative of the information content analysis of Landsat-8 operational Land imager for water resource management. This work studies the use of the principal component analysis as a preprocessing technique for the classification of Multi spectral images.

Keywords: Operational Land imager (OLI), Principal Component analysis (PCA), Pre-processing, MultiSpectralSensor(MSS), Optimum Index Factors (OIF).

I.INTRODUCTION

The delineation of geomorphic features of the island of Lesvos,Greece has been done by combining the data analysis of LANDSAT-5/TM. Image analysis techniques used in study is Principal component analysis (PCA) and false colour composite (FCC). These techniques led to the creation of enhanced satellite images with respect to the topographic and geomorphologic characteristics of the island.[4]. When two often-cited statistical band selection methods of image visualization provide significantly different results when applied to the same data set. [1]. The availability of hyper spectral images expands the capability of using image classification to study detailed characteristics of objects, but at a cost of having to deal with huge data sets. Recent studies have suggested the benefit and efficiency of using the principal component analysis technique as a pre-processing step for the classification of hyper spectral images [6].

Optimum Index Factor (OIF) could provide improved classification accuracy of the various categories on the satellite images of the individual years as well as stacked images of two different years as compared to all the features considered together [5]. The OIF identifies the combination that contains the most information and the least amount of duplication. To minimize potential information loss, the OIF method can also used with principal- components analysis [2].

The Normalized Difference Water Index (NDWI) is a new method that has been developed to delineate open water features and enhance their presence in remotely-sensed digital imagery [3].

Study region: The area around Nagarjun sagar was chosen as a test site. The Latitude and Longitude values of test site are as fallows 16.575967 N & 79.312402 E.

II. METHODOLOGY:

For deriving the information related to water bodies with multi spectral data in current study, Erdas Imagine 15 is used. The approach involves generation of principal component transform of OLI multispectral data and deriving information of water related features. Information extraction is done using the Principal Component Analysis (PCA) which is an existing module in Erdas Imagine. Another software ILWIS is used for carrying out Optimum Index Factor (OIF).

A. Principal Component Analysis

To extract the information of water bodies the multispectral images captured from space in different regions of EMR is used. All the bands of same satellite data are highly correlated which means redundancy of information. Principal component analysis aims at converting original multispectral data with high correlation to uncorrelated transforms. The principal component analysis for a particular image gets repeated based on number of individual bands in the image. In the transformed image the maximum variance lies along the first axis i.e PC1, followed by second axis i.e PC2 and so on least variance (complete noise data) will present in the last axis i.e last PC.

The PCA process is implemented in two steps. Step i) n*n covariance matrix from the bands is derived. Step ii) Eigen values and Eigen matrix are computed.

$$\sum_{Y} = \phi T \sum_{X} \phi = \begin{vmatrix} \lambda_1 O \ldots\ldots\ldots\ldots O.. \\ \ldots\ldots \lambda_2 \\ \ldots\ldots\ldots\ldots\ldots \lambda_3 \\ . \\ .O \ldots\ldots\ldots\ldots\ldots\ldots \lambda_n \end{vmatrix}$$

ΣX = covariance matrix of original image bands,
Σ*Y* =uncorrelated covariance matrix of uncorrelated bands,
Φ = eigen vector matrix,
λ_i's = eigenvalues such that $\lambda_i > \lambda_j$ for $i > j$.
Percentage of total variance carried by each PCA using below formula

$$Var_i = (\lambda_i \div \sum_{k=1}^{n} \lambda_k) \times 100$$

B. Optimum Index Factor (OIF)

In case of Multispectral image the analyst prefers to select minimum number of satellite band data which gives maximum information about image. Optimum Index factor solves this issue by selecting a set of three spectral band combination which gives maximum variance among all the three spectral band combination.

OIF is calculated as

$$OIF = (\sum_{i=1}^{i=n} Std_i \div \sum_{i=1}^{i=j} Corr_{ij})$$

Where Std_i = standard deviation & $Corr_{ij}$ = absolute value of correlation coefficient.

C. Normalised Difference Water Index(NDWI):

The NDWI image was generated by using green and NIR bands of OLI-8 data using the following formula.The use of Normalised Difference Water Index (NDWI) is the delineation of open water features.

NDWI= (GREEN-NIR/GREEN +NIR)

III. RESULTS and CONCLUSIONS:

The section is divided into two sub sections namely

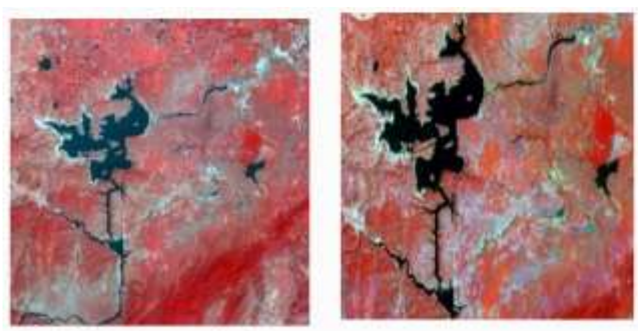
1. Optimum Index factor dealing with minimum number of band combinations which gives unique information that is present in image.
2. Principal component Analysis aims at converting original multispectral data with high correlation to uncorrelated transforms

A. Optimum Index Factor:

Visual comparison is made for the FCC obtained from all the bands of satellite data and FCC derived from combination of OLI bands whose OIF value is more, which reveals a good improvement in water content analysis.

Table1: Optimum Index factor for various Band combinations

S.no	Combination	ΣSD	ΣR	OIF= ΣSD/ ΣR
1	123	43.297	2.8908	14.97751487
2	124	39.826	2.8081	14.18254336
3	**125**	**40.599**	**1.8964**	**21.40845813**
4	126	38.691	2.5188	15.36088614
5	127	37.943	2.6417	14.36309952
6	134	24.228	2.7203	8.906370621
7	135	25.001	1.8088	13.82339931
8	136	23.093	2.431	9.49938297
9	137	22.345	2.5539	8.749363718
10	145	21.55	1.7259	12.47465091
11	146	19.622	2.3483	8.355831878
12	147	18.874	2.4712	7.637584979
13	156	20.395	1.4366	14.19671446
14	157	19.647	1.5595	12.59820868
15	167	17.739	2.1819	8.130070122
16	234	30.817	2.8075	10.97666963
17	235	31.59	1.886	16.74973489
18	236	29.682	2.5331	11.71765821
19	237	28.934	2.6479	10.92714982
20	245	28.119	1.8121	15.51735555
21	246	26.211	2.4592	10.65834418
22	247	25.463	2.574	9.892385392
23	256	26.984	1.5377	17.5482864
24	257	26.236	1.6525	15.87655068
25	345	12.521	2.1285	5.882546394
26	346	10.613	2.7253	3.894250174
27	356	7.915	1.9739	4.009828239
28	357	7.167	2.0577	3.483015017
29	367	5.259	2.7872	1.886839839
30	567	6.032	1.7474	3.451985807



Standard false colour composite of test site of all bands

False colour composite of test site using bands 1,2,5

Figure 1: Comparision of FCC among all Bands and Bands 1,2,5

A. Principal Component Analysis:

The details of covariance, Eigen vectors are shown in below tables. Eigen values and Eigen vectors computed for 7*7 matrix is shown in table 4. The variance present in the first PC is 19378300.18which accounts for 73.57% of the image variance, followed by second PC whose variance is (24.05%). The last PC i.e. seventh PC accounts for only (0.00003%) of the variance. While PC1 exhibits overall brightness of the image in which water resources are identified clearly.

Table 2: Statistics of Test site

Band	Min	Max	Mean	Standard deviation
1	0	255	84.038	15.239
2	8	252	145.743	21.828
3	42	255	155.904	6.23
4	49	255	76.166	2.759
5	68	255	126.125	3.532
6	89	146	114.015	1.624
7	107	133	117.126	0.876
SUM				52.088

Table 3 : Covariance matrix

Band	Band1	Band2	Band3	Band4	Band5	Band6	Band7
1	157406.06	195793.54	260603.1	433450.8	-99787.5	628247.3	701939.6
2	195793.54	248822.56	341909.73	576919.3	-73886.7	883729.8	956527.3
3	260603.1	341909.73	530800.79	922782.2	353758.6	1690814	1659500
4	433450.84	576919.31	922782.23	1780187	441708.1	3397712	3384458
5	99787.52	-73886.65	353758.61	441708.1	7330105	3943399	1910281
6	628247.27	883729.84	1690813.61	3397712	3943399	8938785	7746818
7	701939.55	956527.31	1659499.61	3384458	1910281	7746818	7351069

Table 4: Eigen Vector data

Eigen vector	Band1	Band2	Band3	Band4	Band5	Band6	Band7
1	0.0502	-0.0775	0.3464	-0.1568	0.4651	-0.4477	-0.6554
2	0.07	-0.0958	0.4176	-0.206	0.4256	-0.2155	0.7357
3	0.1331	-0.0923	0.5104	-0.1925	0.06054	0.8025	-0.1683
4	0.2618	-0.2192	0.5114	0.0914	-0.716	-0.3173	0.003
5	0.3266	0.9097	0.1917	0.1663	0.01273	-0.0306	0.0088
6	0.6746	-0.0489	- 0.3674	-0.6338	-0.0671	0.03301	-0.01031
7	0.5869	-0.3132	- 0.1077	0.6768	0.2852	0.0785	0.0119
E value	19378300.18	6334683.762	477525	97392.24	40269.48	8098.037	906.0802
Percent variance	73.57	24.05	1.8	0.3	0.15	0.0005	0.00003

Principal Component Transform for 7 bands of OLI data:

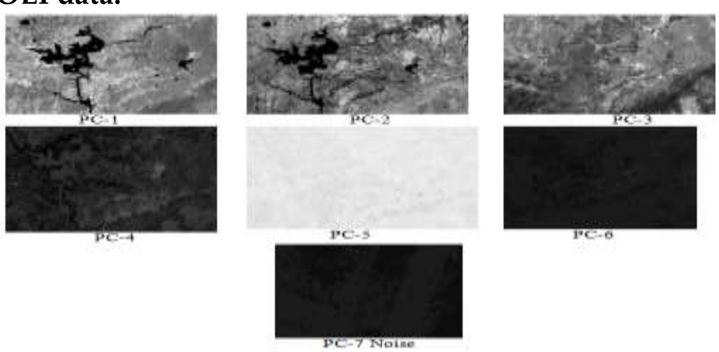


Figure 2: Principal Component Transform of Land sat OLI data

A. Detection of Terrain features:

A qualitative evaluation of transformed images with respect to delineation of terrain features is given below

C1 Optimum Index Factor:

As evident from Table 1 the band combination 1,2, &5 accounts for a maximum OIF value (21.40) indicating thereby the availability of maximum terrain information. With respect to information on water resources and other terrain features, a comparison of FCC prepared from all the bands with the one generated using bands 1,2,5 reveals that the overall image contrast amongst various terrain features is more in case of FCC prepared using spectral band with maximum OIF value. Furthermore in contrast between crops and forest is appreciably better in FCC of maximum OIF value images as compared to standard FCC image.

C2 Principal Component Transform:

Water bodies stand out very well in PC1 image. In addition drainage network required for various hydrological studies including modelling is very clear. However, the contrast between forest and crop land is relatively poor.

In PC2 image paddy crop has come out very well incidentally the contrast between land and water bodies is very poor. In PC3 the contrast between land features and land water boundary is equally poor.

C3 Normalised Difference Water Index (NDWI):

Since the focus of study was on delineation of water and its related features, the NDWI image has served as very good database for detection of water bodies. The water bodies are seen as bright white features. The pixel values varies from -0.196 to 0.724. As evident from figure-3 the water bodies-both Natural as well as manmade are exhibited vividly in very light gray tone. Interestingly, the coastal water in the lower right of the image is seen as white colour. This area is part of Bay of Bengal. Vegetation over hills (Forest) is manifested as dark to very dark gray tone. Crop lands along the coastal plains could be seen as medium gray tone.

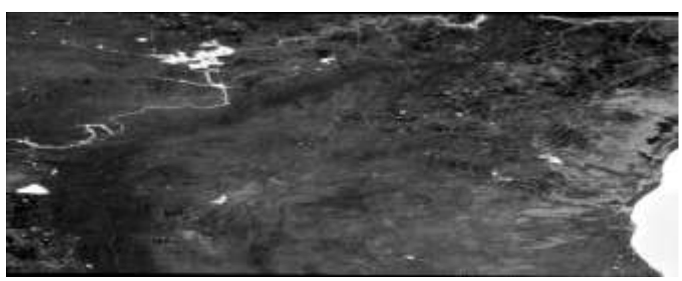


Figure3: Delineation of water resources

IV Conclusion:

To optimise the number of spectral bands for identification of water resource management three data sets namely original Landsat -8 OLI band data, a band triplet with maximum OIF value, and the first three principal components of Landsat-8 OLI bands were analyzed. All the water resources are highlighted which provides an easy view for identifying them. Interestingly, a band triplet with the maximum optimum index factor (OIF) value 21.40845813 (Landsat-8 OLI band 1, 2 and 5) showed clear identification of water resources with fewer number of bands.

Similarly the PC's 1,2,3 showed maximum amount of covariance data for identifying of water resources. The results clearly show the potential of using data transforms for detection of water resources using multispectral data of satellite.

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