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Radiance to Reflectance Conversion Effects on Landsat TM Images

Salah A. H. Saleh*, Enaam K. H AL-Kabi *, Nehad A. Karm**

* *Ministry of science and technology.*

** *Department of Astronomy, College of science, University of Baghdad. Baghdad-Iraq.*

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Abstract

In this research digital numbers (DNs) for Landsat-5 TM images was converted to reflectance values, at first DNs converted to radiance by corrected for Gain and Offset values of the particular spectral TM band. Then converted these radiance values to spectral reflectance by correcting the atmospheric effects.
To study the effects of the conversion, digital image processing techniques were applied for both images (DNs and Reflectance), such as enhancement by histogram equalization, and geometrical correction. Image classification (supervised and unsupervised) also applied as comparative criteria.
The analysis of the results shows that the reflectance image gave better classification accuracy for supervised and unsupervised classification than image DNs while conversion DNs to reflectance image does not affect its geometrical properties.

الخلاصة

في هذا البحث تم تحويل القيم الرقمية DNs لكل حزمة من صوره القمر الصناعي لاندسات - TM 5 الى قيم الانعكاسية Reflectance. في بادئ الامر تم تحويل DNs الى الاشعاعية ثم الى الانعكاسية الطيفية من خلال تصحيح تأثير الغلاف الجوي.
وتم تطبيق بعض تقنيات المعالجة الرقميه على كلتا الصورتين الاصلية DNs والانعكاسيه Reflectance كطريقه تساوي المنحني التكراري والتصحيح الهندسي لملاحظه تأثير عملية تحويل الصور وتم كذلك تطبيق تقنيه تصنيف الصور (موجه وغير موجه) كمقياس للمقارنة بين الصور الناتجه.
من تحليل النتائج تبين بأن صورة الانعكاسية (Reflectance) تعطي دقة تصنيف افضل في التصنيف الموجه وغير الموجه من صورة DNs بينما تحويل DNs الى انعكاسية Reflectance لايؤثر على الصفات الهندسيه للصورة.

Introduction

Satellite sensors, such as TM, measure radiance reflected from the Earth surface at different wavelengths. However radiance is affected by various factors. As accurate data is required; these effects must be removed from radiance to retain only variations caused by the reflectance of the earth surface objects. [2]
The reflectance nature of an object must be understood if it is going to be identified on satellite image. In- situ or reference data is often collected at the time of image acquisition .One form of reference data is the ground – based measurement of the object reflectance. This might be done in the laboratory or in the field using field radiometer. This device measures, as a function of wavelength, the energy coming from an object within its view. It is used primarily to prepare spectral reflectance curves for various objects. Multiband Radiometer measures

radiation in a series of discrete spectral bands, rather than over a continuous range. These bands are similar to the bands used by satellite sensors [4].

All Remote Sensing satellites collect their data as digital format (digital numbers - DNs) with different gray level. These DNs dose not represented real values of spectral reflectance of earth targets. The conversion of DNs to reflectance value allows comparison between various satellites data with different grey levels, also it is the best way to compare between laboratories and filed spectral data with satellite images data, that could be quite useful in labeling training samples for supervised classification

The scope of this study is to evaluate of DNs to reflectance conversion process on the radiometric and geometric characteristics of Landsat TM data.

Calibration of Landsat TM Data

Each spectral band of the TM has its own response function, and its characteristics are monitored using inboard calibration lamp (and temperature references for the thermal channel). The absolute spectral radiance output of the calibration sources is known from pre-launch calibration and is assumed to be stable over the life of the sensor. Thus, the inboard calibration sources form the basis for constructing the radiometric response function by relating known radiance values incident on the detectors to the resulting DN.

The relationship between radiance (L) and digital number (DN) can be written as [10]

L= Gain *DN + Bias............................(1)

Where:

L= spectral radiance measured over spectral bandwidth of Channel ($mwcm^{-2}$ st^{-} DN=digital number value recorded

Gain = $(L_{max} - L_{min}) / 255$ (Slope of response function, see figure (1)

Bias =L_{min} (Intercept of response function; see figure (1)

L_{max} =radiance measured at detector saturation in [$mwcm^{-2}$ sr^{-1}]

L_{min} =Lowest radiance measured by detector in [$mwcm^{-2}$ sr^{-1}]

While, the Reflectance in a single band is calculate

Reflectance = $[\pi/E*\sin(\alpha)]*L$ ....(2)

Where E = Irradiance in $mwcm^{-2}$ at the top of the atmosphere

α = solar elevation angle (36 degree).

Table (1) shows the value of Lmin, L_{max}, Gain, Bias and irradiance values for Landsat-5 bands [11].

TM	L_{min}	L_{max}	Gain	Bias	irradiance (E)
Band1	-0.0100	1.00490	0.00398	-0.0100	12.91620
Band2	-0.0232	2.43476	0.00964	-0.0232	14.99780
Band3	-0.0078	1.36920	0.00540	-0.0078	10.43190
Band4	-0.0193	2.64035	0.01043	-0.0193	13.40160
Band5	-0.0080	0.59125	0.00235	-0.0080	4.758810
Band7	-0.0040	0.38870	0.00154	-0.0040	1.877904

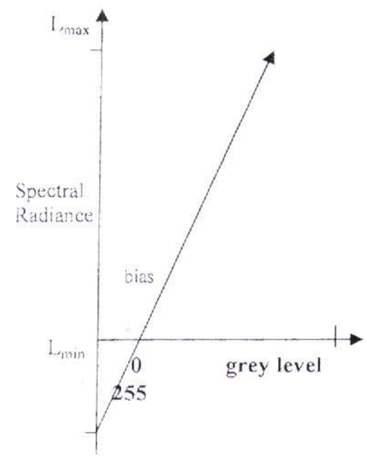


Figure (1) Inverse of radiometric response function for an individual TM channel. [11]

Conversion of TM Digital Numbers to Spectral Radiance

Part of landsat TM image (path- 170, row-35) for Hamam – Alil reion in Al – Mousl area was used as digital test image(see figure(3-A)). The acquisition date of that image was February 1988. Only three band of that image have been used, band 3 (0.63-0.96 μm), band 5(1.55-1.75μm) and band 7(2.08-2.35μm).

The conversion of DN to spectral reflectance can be split into three steps, as it shown in the following block diagram (figure – 2).

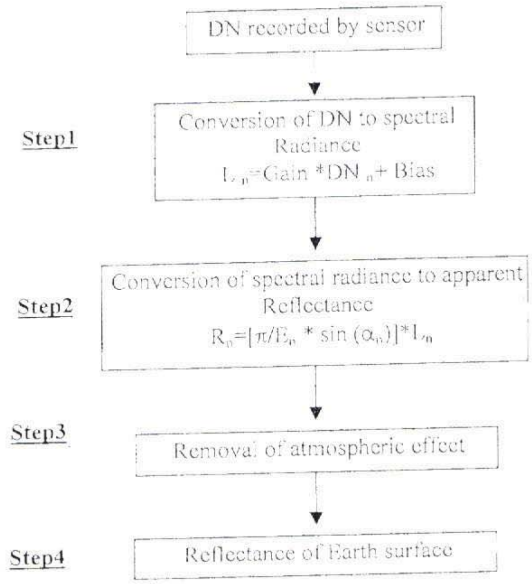
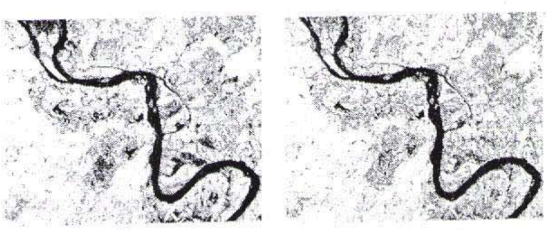


Figure (2) Block diagram of conversion steps

The reflectance image shown in figure (3-b). Then uniform DNs spatial profile for water, vegetation and soil on TM image were selected and its corresponding reflectance values shown in table (2).

Objects	BAND 3 DN Ref%		BAND 5 DN Ref%		BAND 7 DN Ref%	
Water	52	0.14032	27	0.06146	10	0.02889
Soil	83	0.22596	31	0.3352	109	0.44206
Vegetation	54	0.14662	75	0.18688	50	0.19328



(A) (B)

Figure (3) Landsat TM false color image A- DN, B- Reflectance image

Histogram Adjustments

This method was used to remove the effect of atmosphere (dark pixel subtraction) from satellite images by evaluating the histogram of image bands.

Table (3) shows the minimum and maximum value of TM bands before applying histogram adjustment atmospheric scattering correction

Bands	Dark pixel value for DN Images (Min DN)	Brightness pixel value for DN Images (Max DN)
3	22	255
5	0	255
7	0	255

Dark subtraction algorithm model is based on a subtractive bias value for each spectral band. The bias was determined by evaluating the original histogram as discussed previously. So the output value is given as:

Output Image=input image–DN minimum ..(3)

$[DN\ 3]_{output} = [DN\ 3]_{input}\ .22$

The value of minimum and maximum of TM band-3 after applying this model as atmospheric scattering correction given as:

Band	Dark pixel value for DN Images (Min DN)	Brightness pixel value for DN Images (Max DN)
3	0	233

Geometrical Correction for TM Image

Geometric correction for DNs and reflectance images were conducted as it shown in figure (4). The geometric block diagram in figure (4). The geometric corrected images for DNs and reflectance data shown in figure (5-A and 5-B).

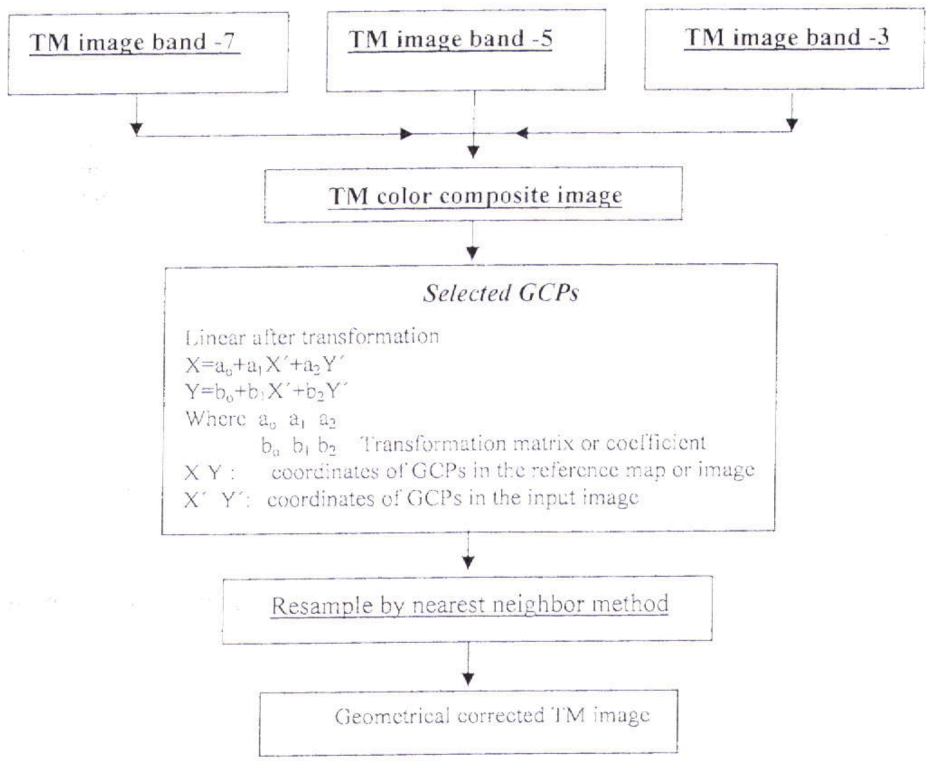
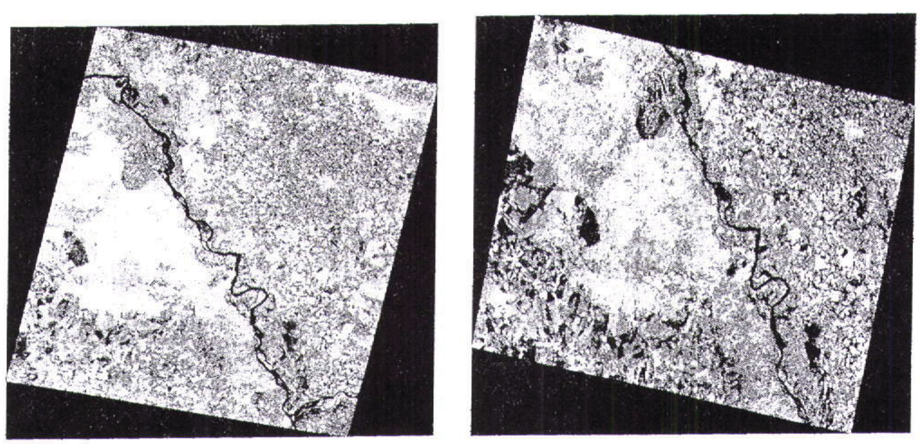


Figure (4) block diagram of geometrical correction steps



(A) (B)

Figure (5) geometrical correction for (A) Reflectance and (B) Digital image

Unsupervised Classification

Figures (6) – (7) and tables (4)- (5), shows the result of applying unsupervised classification (K-mean) for digital and reflectance images.

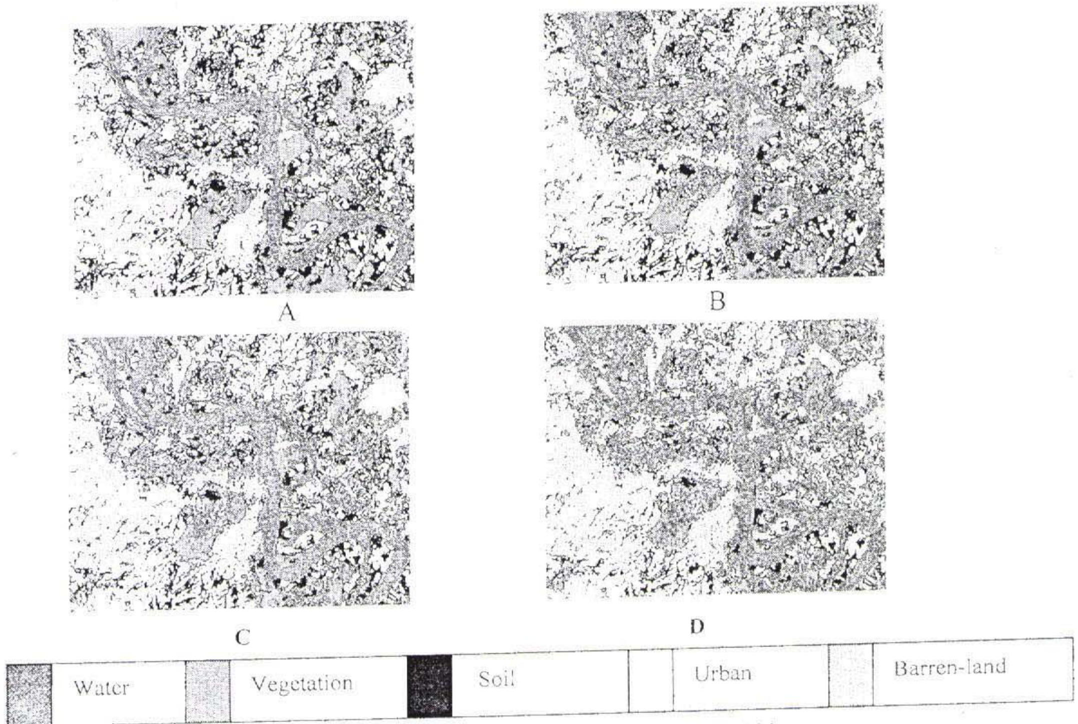


Figure (6) unsupervised classification by K-mean method of DN image
B-10 iterations B-5 iterations C- 4 iterations D-2 iterations

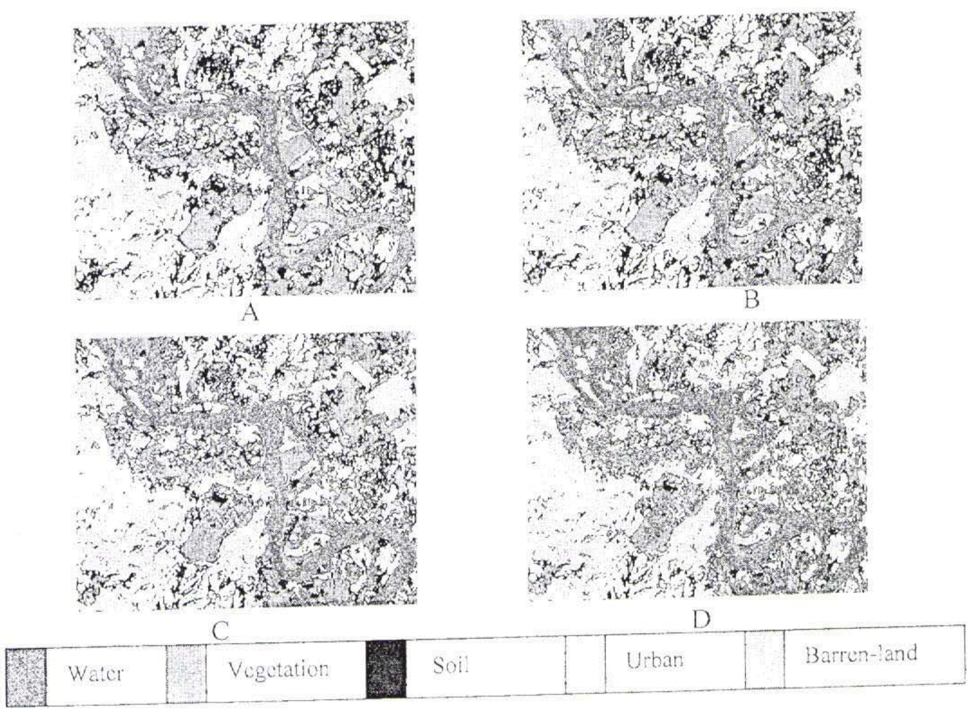


Figure (7) unsupervised classification by K-mean method of reflectance image
A-10 iterations B-5 iterations C- 4 iterations D-2 iterations

Table (4) classification statistics summary report of DN unsupervised image by K-mean method.

Classes	10- Iterations	5-Iterations	4-Iterations	2-Iterations
Water	10094(8,56%)	13452(11.419%)	15363(13.04%)	20398(17.31%)
Vegetation	22666(19.24%)	24250(20.58%)	23746(20.15%)	21815(18.51%)
Soil	35115(29.80%)	31435(26.68%)	29478(25.02%)	23949(20.33%)
Urban	33243(28.21%)	30624(25.99%)	30164(25.60%)	28862(24.50%)
Barren land	16682(14.16%)	18039(15.31%)	19049(16.17%)	22776(19.33%)

Table (4.7) classification statistics summary report of Reflectance

Table (5) classification statistics summary report of reflectance unsupervised image by K-mean method

Classes	10- Iterations	5-Iterations	4-Iterations	2-Iterations
Water	9805(8.32%)	11379(9.65%)	13098(11.12%)	18876(16.02%)
Vegetation	21617(18.35%)	24246(20.58%)	24228(20.56%)	21628(18.35%)
Soil	32954(27.94%)	30938(26.26%)	28943(24.56%)	23508(19.95%)
Urban	36184(30.71%)	32911(27.93%)	32239(27.36%)	31198(26.48%)
Barren land	17240(14.63%)	18326(15.55%)	19292(16.37%)	22590(19.17%)

Supervised Classification

Figure (8) and table (6) shows the result of supervised classification for DN and reflectance images by methods of maximum likelihood (MLC) and minimum distance (Min dist) classification.

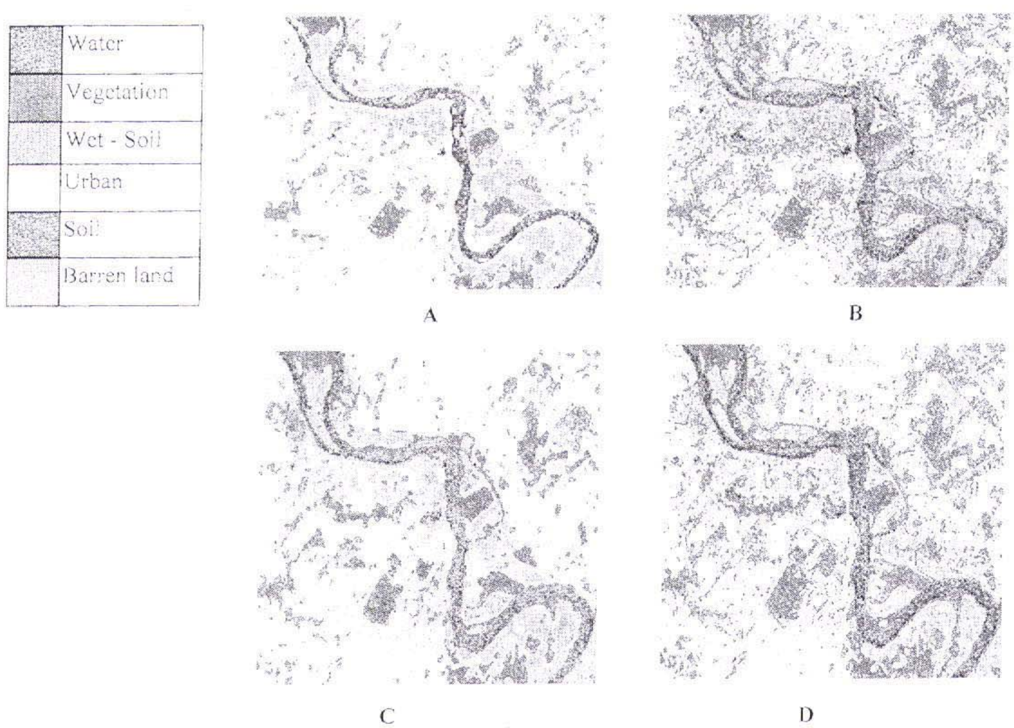


Figure (8) supervised classification of Reflectance image and DN image
A-DN Image by MLC B- DN image by Min dist. C- Reflectance image by MLC D- Reflectance image by Min dist.

Table (6) Supervised classification statistics summary report for digital and reflectance images

Classes	DN by MLC	REF by MLC	DN by MIN	REF by MIN
Water	7317(6.2%)	8141(6.91%)	952(8.08%)	9033(7.66%)
Vegetation	9998(8.5%)	16344(13.87%)	2566(21.78%)	26286(22.31%)
Soil	2461(2.1%)	5185(4.40%)	10766(9.14%)	7158(6.08%)
Urban	8445(1.16%)	5896(5.00%)	19455(16.51%)	24675(20.94%)
Wet-soil	11641(9.88%)	12591(10.69%)	13985(11.87%)	6795(5.76%)
Barren land	77938(66.16%)	69643(59.12%)	38414(32.6%)	43843(37.21%)

Conclusion

The conversion of DNs to reflectance value allows comparison laboratory and filed spectral data with satellite images data, that could be quite useful in labeling training samples for supervised classification. The result shows that the conversion process had no effect on geometrical properties of the image. The supervised and un-supervised classification shows that reflectance image gave better results compared with DNs image, and that due to the conversion process minimize the effects of sensor and atmosphere.

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