DOI: 10.21120/LE/10/2/2 **Landscape & Environment 10 (2) 2016. 63-74**

CORRECTION OF ATMOSPHERIC HAZE OF IRS-1C LISS-III MULTISPECTRAL SATELLITE IMAGERY: AN EMPIRICAL AND SEMI-EMPIRICAL BASED APPROACH

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Received 23 April 2016, accepted in revised form 14 June 2016

Abstract

The atmospheric effect greatly affects the quality of satellite data and mostly found in the polluted urban area in the great extent. In this paper, the atmospheric correction has been carried out on IRS-1C LISS-III multispectral satellite image for efficient results for the Raipur city, India. The atmospheric conditions during satellite data acquisition was very clear hence very clear relative scattering model of improved dark object subtraction method for the correction of atmospheric effects in the data has been carried out to produce the realistic results. The haze values (HV) for green band (band 2), red band (band 3), NIR band (band 4) and SWIR (band 5) are 79, 53, 54 and 124, respectively; were used for the corrections of haze effects using simple dark object subtraction method (SDOS). But the final predicted haze value (FPHV) for these bands are 79, 49.85, 21.31 and 0.13 that were used for the corrections of haze effects applying improved dark object subtraction method (IDOS). We found that IDOS method produces very realistic results when compared with SDOS method for urban land use mapping and change detection analysis. Consequently, ATCOR2 model provides better results when compared with SDOS and IDOS in the study.

Keywords: atmospheric correction; IDOS; ATCOR2; Haze; India

1. Introduction

Remote sensing data is widely used in studies namely groundwater (Mukherjee et al. 2007; Singh et al. 2010a; Singh et al. 2013; Singh et al. 2015a), river water quality (Srivastava et al. 2011), coastal water (Kumar et al. 2015), lake and wetlands (Thakur et al. 2012a; Thakur et al. 2012b; Amin et al. 2014; Singh et al. 2016a), land use/land cover mapping (Singh et al. 2010b; Singh et al. 2013; Singh et al. 2014a: Singh et al. 2014b), land use change trajectories (Srivastava et al. 2013), land use/land cover modeling (Singh et al. 2015b; Mustak et al. 2015), crop suitability (Mustak et al. 2015), urban land use dynamics (Amin et al. 2012), hydrological modeling (Narsimlu et al. 2015), forest mapping (Singh et al. 2012), cyclone tracking (Islam et al. 2015), soil characterization (Paudel et al. 2015), climate change studies (Srivastava et al. 2015), slope estimation (Szabó et al. 2015), landscape ecology (Singh et al. 2016b), ocean studies (Pandey and Singh 2010a; Pandey and Singh 2010b) and watershed management (Yadav et al. 2014). The raw data which is affected by panoramic distortion, earth curvature, failure of sensor detector and detector line losses which are primarily corrected by data providers. But generally the atmospheric effect is not corrected by data providers; it should be done by the users as a pre-processing task. The correction is required in the satellite imageries because visible bands of shorter wavelength are highly affected by atmospheric scattering especially of Rayleigh scattering which is caused by suspended gases, water vapor and aerosols (Yong et al. 2001; Chen 2004; Saha et al. 2005; Gong et al. 2008; Norjamaki and Tokla, 2007; Tyagi – Udhav 2011) which are added as a hazy radiance value instead of actual radiance value which reduced the scene reality of the remotely sensed data and hence such addition is called additive effects of atmosphere in the remote sensing data. The atmospheric effects mostly found in the polluted urban area in the great extent and the correction of such atmospheric effects are mostly carried out for the study of land use and land cover mapping and change detection analysis. The removal of atmospheric additive effects can be done by simple dark object subtraction (SDOS) method and improved dark object subtraction (IDOS) method for multi-band satellite image. SDOS method is a first order atmospheric correction which is better than no-correction at all (Chavez 1988). In this method, constant haze value (DN) of each individual spectral bands are selected using minimum DN value in the histogram from the entire scene is thus attributed to the effect of the atmosphere and is subtracted from each spectral bands (Chavez 1989). The IDOS method which tends to correct the haze in terms of atmospheric scattering and path radiance based on the power law of relative scattering effect of atmosphere (Lillesand – Kiefer 2000). The effects of corrections were studied in urban environment. The image attributes was used for comparing the performance of the correction methods. Overall, the ATCOR2 method performed better than IDOS. According to Teillet (1986), the reflectance of the objects recorded by the artificial satellite sensors is generally affected by atmospheric absorption and scattering, sensor-target-illumination geometry and sensor calibration. These affect the actual reflectance of the objects that subsequently affects the extraction of information from satellite images. There has been considerable attention in research on the need too and the ways of correction of the satellite data from atmospheric effects (Mustak 2013; Song et al. 2000; Chavez 1988; Chavez 1996; Mahiny and Turner 2007). In addition the COST model is an image based absolute correction method, it uses only the cosine of sun zenith angle (cos(TZ)) as an acceptable parameter for approximating the effects of absorption by atmospheric gases and Rayleigh scattering (Mahiny and Turner 2007). The 6S model predicts the reflectance of objects at the top of the atmosphere using information about the surface reflectance and atmospheric conditions (Mahiny and Turner 2007). The meteorological visibility, type of sensor, sun zenith and azimuth, date and time of image acquisition, and latitude and longitude of scene center are needed to run the 6S model. The ATCOR2 model needs path radiance, reflected radiation from the viewed pixel and radiation from the neighborhood, atmospheric conditions (water vapor content, aerosol type, visibility) for a scene can be estimated using the SPECTRA module, finally the surface reflectance spectrum of a target in the scene can be viewed as a function of the selected atmospheric parameters. In this paper, IDOS method of very clear Relative Scattering Model (RCM) is applied for haze correction which produced the very realistic results than SDOS method. Similarly, ATCOR2 provides better results as compared to above mentioned two methods. The study is based on following objectives as (i) to find out the haze values in the data and (ii) to remove the haze values and improve the scene reality of the data for urban land use mapping and change detection analysis.

Table 1. Satellite data use for atmospheric haze correction (Source: NDC, India)

Date of acquisition	Satellite	Sensor	Path/Raw	GSD
20/02/2001	IRS-1C	LISS-III	102/57	23.5 m

Table 2. Details of ATCOR2 model

Time	Latitude	Longitude	Solar Zenith	Solar Azimuth	Scene Visibility
10:42:52 Am	21^{0}15'N	81^0 42'E	65.9^0	246.8^0	10 km

2. Study Area

The whole Raipur city including standard urban area of old Raipur city and standard urban area of Naya Raipur city is situated in the Dharsiwa tehsil and in some parts of the Arang and Abhanpur tehsils of Raipur district has selected as the study area. The study area extends in between 21°04'N to 21°26'N latitudes and 81°30'E to 81°52'E longitudes covering an area of 831.49 km^2 on Chhattisgarh plain with an average 236 metre elevation above mean sea level. The city occupies the north-western part of Raipur district and located on the eastern part of the Mahanadi basin as well as the fertile valley of river which is the principal rivers of this city. The temperature is 34.3°C in summer and fall to 19°C in winter having an average rainfall of 1400 mm. The climate of this region is characteristics by a hot and dry summer and well distributed rains in the monsoon season.

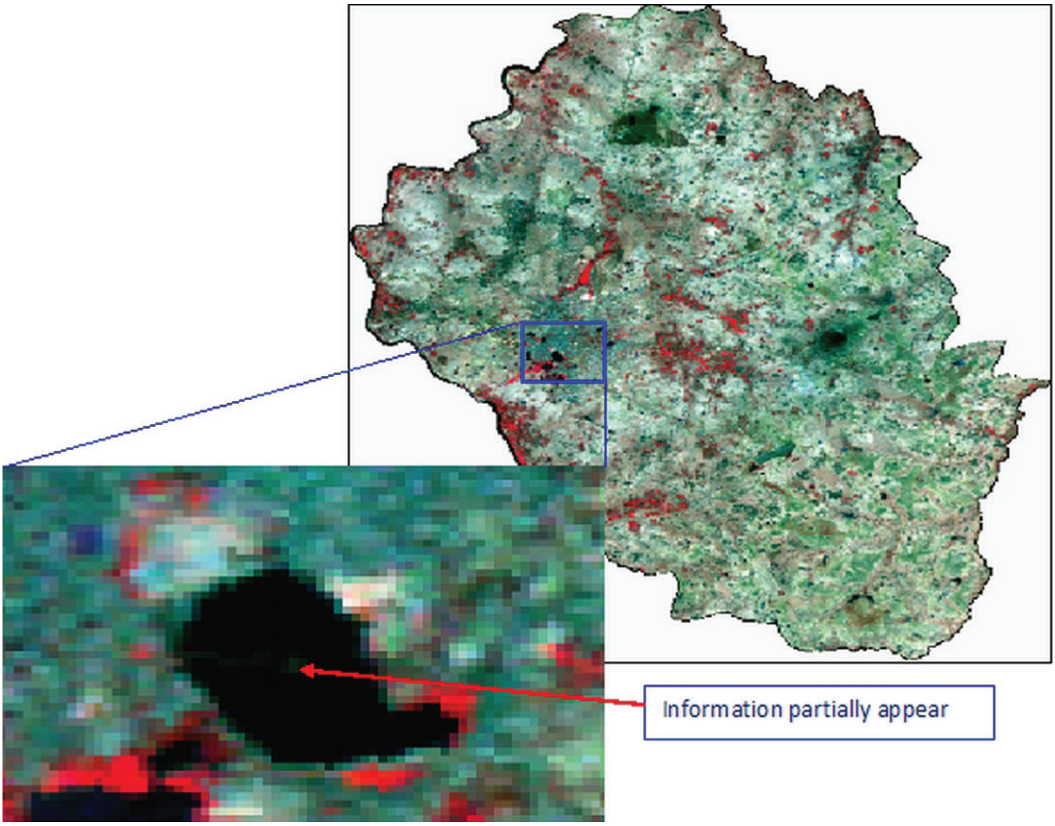


Fig. 1a. Original uncorrected IRS-1C LISS-III multispectral satellites image, acquired on 20th February 2001

The population of the Raipur city is 1428623 persons and 71.95% literate (Census 2011). The city is a fast developing important industrial centre and well connected with various major cities of India by road, rail and air transporting systems. The Raipur city is situated along the Mumbai-Nagpur-Hawrah mainline. In this regards, the Raipur is an important city of Chhattisgarh as well as India; so the author has selected the Raipur city as the study area.

3. Material and Methods

Database and methodology

The study has carried out on IRS-1C LISS-III multispectral satellite data which is collected from National Data Centre (NDC), National Remote Sensing Centre (NRSC), Indian Space Research Organization (ISRO), Balanagar, Hyderabad, Andhra Pradesh, India. The climatic data has collected from Indira Gandhi Agricultural University, Raipur, Chhattisgarh, India and District Statistical Handbook, Raipur. The study of climatic data is used to find out the climatic conditions during satellite data acquisition and it suggests that the study area was having very clear atmospheric conditions during satellite data acquisition. The details of satellite data and method are given in Table 1. and 2. and Figure 1a. and 1b.

4. Results and Discussions

Simple Dark Object Subtraction (SDOS)

SDOS is a very simple image-based method of atmospheric correction which assumes that there are at least a few pixels within an image which should be black (% reflectance) and such black reflectance is termed as dark object which are clear water body and shadows whose DN values zero (0) or close to zero in the image (Chavez 1988). This method is widely used for classification and change detection application (Spanner et al. 1990). SDOS method is a first order atmospheric correction which is better than no-correction at all (Chavez, 1988). In this method, constant haze values (DN) of each individual spectral band are selected as minimum DN value in the histogram from the entire scene and is thus attributed to the effect of the atmosphere which is subtracted from the each spectral bands (Chavez 1989).

Improved Dark Object Subtraction (IDOS)

IDOS method which tends to correct the haze in terms of atmospheric scattering and path radiance based on the power law of relative scattering effect of atmosphere

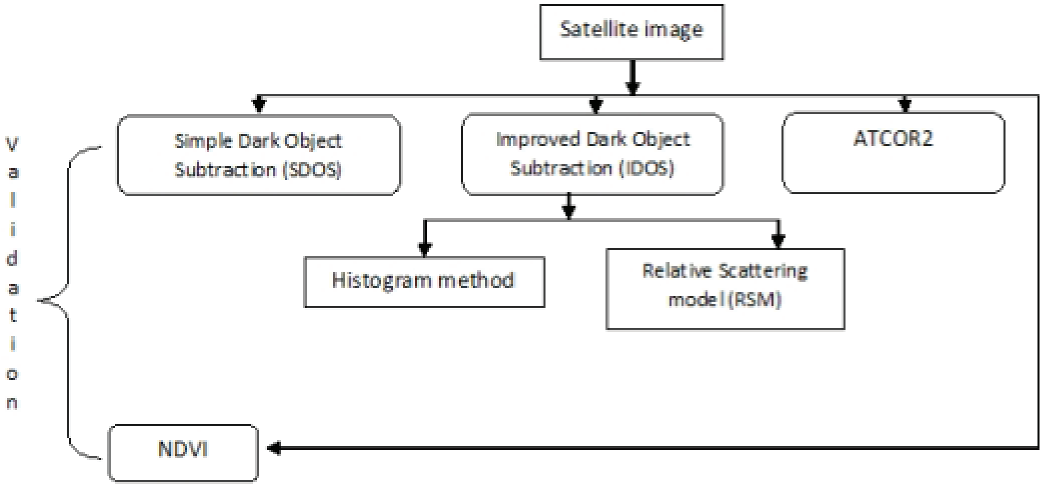


Fig. 1b. Flow chart of adopted methodology

Table 3. Radiometric details of Satellite data and selection of Haze Values using Histogram Method

Spectral Range (µm)	Bands	Radiometry	Lmax	Lmin	Haze values (DN)
			mW cm^{-2} ster^{-1} µm^{-1}		
Band 2=0.52-0.59	Green	7 Bits (0-127)	14.45	1.76	SHV=79
Band 3= 0.62-0.68	Red		17.03	1.54	53
Band 4=0.77-0. 86	NIR		17.19	1.09	54
Band 5=1.55-1.70	SWIR		2.42	0.00	124

Table 4. Principle of Relative Scattering Model of Atmospheric effects (Source: Chavez, 1988)

Atmospheric Conditions	Relative Scattering Model (RSM)
Very clear	λ^{-4}
Clear	λ^{-2}
Moderate	λ^{-1}
Hazy	$\lambda^{-0.7}$
Very hazy	$\lambda^{-0.5}$

Table 5. Principle of Relative Scattering Models as percent (%) contributed for each spectral band

Bands	$\lambda^{average}$	Very Clear		Clear		Moderate		Hazy		Very hazy	
		λ^{-4}	%	λ^{-2}	%	λ^{-1}	%	$\lambda^{-0.7}$	%	$\lambda^{-0.5}$	%
2	0.555	10.54	56.82	3.25	43.28	1.80	34.68	1.51	31.99	1.34	29.98
3	0.650	5.60	30.19	2.37	31.55	1.54	29.67	1.35	28.60	1.24	27.74
4	0.815	2.27	12.24	1.51	20.11	1.23	23.70	1.15	24.37	1.11	24.83
5	1.625	0.14	0.75	0.38	5.06	0.62	11.95	0.71	15.04	0.78	17.45
Total	-	**18.55**	**100**	**7.51**	**100**	**5.19**	**100**	**4.72**	**100**	**4.47**	**100**

(Lillesand – Kiefer 2000). IDOS method is the improvement over the SDOS method to minimize the chances of overcorrection of DN in the scene. IDOS method is based on two sub-models such as:

Histogram Method

This method is used to select the haze values such as starting haze value (SHV) in this image and visible band 2 (green) is selected SHV as 79 (Table 3.).

Relative Scattering Model (RSM)

This model is based on two important relative scattering models as Rayleigh (particle size less than the wavelength) and Mie Scattering (particle size same as the wavelength) models (Slater et al. 1983). These two models are based on power law as for Rayleigh scattering effects of atmosphere which acts with the wavelength in imaging systems as inversely proportional to the fourth power of wavelength (λ^{-4}) which means that shorter wavelength of the spectrum are scatter much more than longer wavelengths. This type of scattering is caused by gas molecules which are much smaller than the wavelength of light. The Mie Scattering effects of atmosphere which acts with the wavelength in imaging systems as inversely proportional to the wavelength which vary from λ^{-0} to λ^{-4}, and λ^{-1} for moderate atmosphere and λ-0 for completely cloud cover. But the relative scattering that usually occurs in a real atmosphere that is clear seems to follow more of a λ^{-2} to $\lambda^{-0.4}$ relationship and not a Rayleigh or Mie (Curcio 1961; Slater et al. 1983). Taking this information in account, the relative scattering that occurs in a hazy atmosphere can be approximated as $\lambda^{-0.7}$ to $\lambda^{-0.5}$, if similar

Table 6. Multiplication factors of Relative Scattering Models are used to Predict Haze Values for other bands and Band 2 is selected as SHV is 79

Bands	Very Clear	Clear	Moderate	Hazy	Very hazy
	λ^{-4}	λ^{-2}	λ^{-1}	$\lambda^{-0.7}$	$\lambda^{-0.5}$
2	1.00	1.00	1.00	1.00	1.00
3	0.53	0.73	0.86	0.89	0.93
4	0.22	0.46	0.68	0.76	0.83
5	0.01	0.12	0.34	0.47	0.58

Table 7. Gain, Offset, and Gain Normalization factors

Bands	Gain	Offset	Gain Normalization (NOR_i)
2	14.45	1.76	1.00
3	17.03	1.54	1.18
4	17.19	1.09	1.19
5	2.42	0.00	0.17

Table 8. Final Predict Haze Values of Very Clear Relative Scattering Model

Bands	SDOS	Improved Dark Object Subtraction Method	
	Haze Values	Predicted Haze Values	Final Predicted Haze Values
2	79	77.24	79
3	53	40.94	49.85
4	54	16.99	21.31
5	124	0.77	0.13

power law relationships are used. The critical aspect of the method proposed in this paper is that the haze correction DN value used by SDOS techniques be computed using a RSM to ensure that the haze values do represent, or better approximate, true atmospheric possibilities. Using the information supplied by Curcio (1961) and Slater et al. (1983), and extrapolating to very clear and very hazy atmospheres, one possible set of RSM are (Chavez 1988), Table 4. and 5. The principles of RSM are used to predict haze values (PHV) for each spectral band based on SHV in the IDOS method for the atmospheric haze correction for specific atmospheric conditions. The study area was belonging to very clear atmospheric conditions during satellite data acquisition and hence the correction of atmospheric haze has been carried out based on the principle of very clear RSM. The computation of PHV for different spectral bands from SHV of selected band has been done based on the normalized value of RSM as termed as multiplicative factors showing in Table 6.

The PHV for different spectral bands is computed based on following equation (1) as:

PHV (DN) =IPHV1 of bandi* Multiplicative Factors of next bands (1)

[1] Initial Predicted Haze Value (IPHV) is calculated by subtracting the SHV from offset value, the gain and offset value showing in Table 7.

In this paper, the SHV is 79 for band 2 and the IPHV is 77.24 (SHV-1.76) for this band but the PHV for next spectral bands such as for band 3 is 40.94 (77.24*0.53), band 4 is 16.99 (77.24*0.22) and for band 5 is 0.77 (77.24*0.01) showing in Table 8.

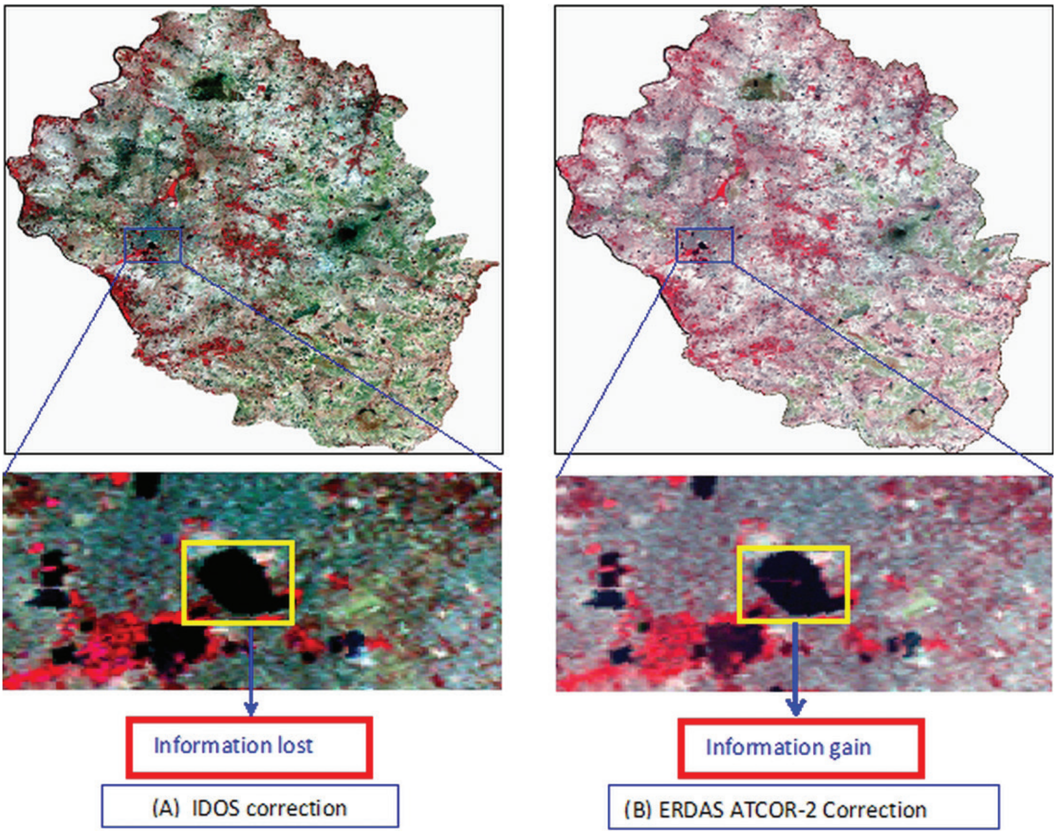
The haze values computed using RSM are not the correct haze values to remove the haze effects from the satellite image. To compute the correct or final predicted haze values (FPHV), the different gain (Lmax) and offset (Lmin) values in the imaging systems has to be adjusted with PHV by means of the addition of offset value and multiplication of normalized gain values. The calculation of normalized gain values along with the offset values.

The calculation of FPHV performed using following equation (2):

$$\text{FPHV (DN)} = \text{NORi} * \text{PHV} + \text{Offset} \quad (2)$$

The FPHV along with the haze values of individual bands and PHV are showing in Table 8. The FPHV is subtracted from each spectral bands and then whole haze corrected bands of satellite image are stacked to prepare a corrected false color composite image (Figure 2.) in Erdas Imagine modeler. The whole work of atmospheric correction is done in ERDAS Imagine 9.2 version. IDOS method is based on the RSM which has been used to compute PHV that are wavelength dependent and highly correlated to each other. Finally, generates realistic results with proper gain and offset normalization. The correction of atmospheric haze has carried out in this paper by the principle of Rayleigh scattering of very clear RCM (Table 8.; Figure 2.).

The haze values selected by histogram method for green band (band 2), red band (band 3), NIR band (band 4) and SWIR (band 5) are 79, 53, 54 and 124 which are used for the corrections of haze effects in SDOS. But the PHV for band 2, band 3, band 4 and band 5 are 77.24, 40.94, 16.99 and 0.77 and FPHV for these bands are 79, 49.85, 21.31 and 0.13 which are used for the corrections of haze effects using IDOS for realistic result.



(A) IDOS correction

(B) ERDAS ATCOR-2 Correction

Fig. 2. Atmospheric haze correction of IRS-1C LISS-III multispectral satellites image

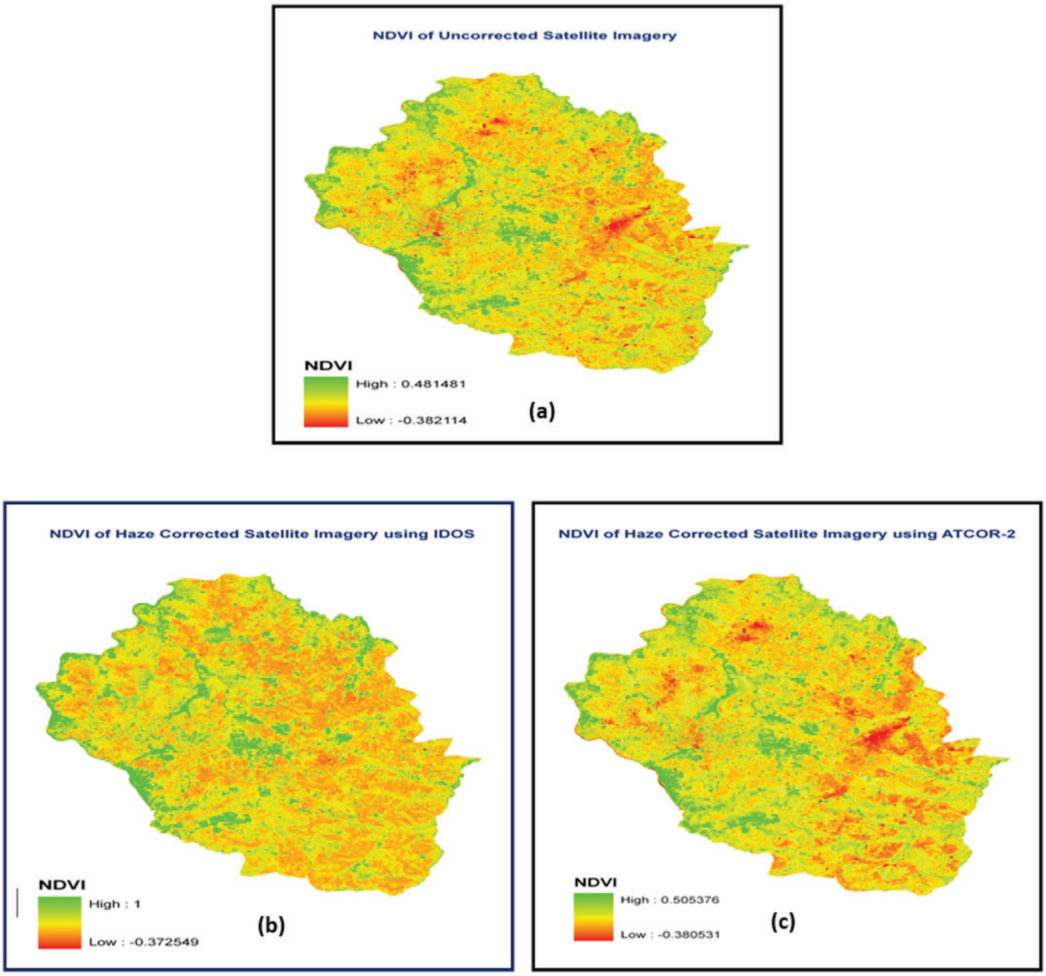


Figure 3 (a) NDVI image (from uncorrected image) (b) NDVI of haze corrected satellite imagery using IDOS (c) NDVI of haze corrected satellite imagery using ATCOR2

There are quite dramatic changes of the haze values resulted from the SDOS method, PHV and FPHV using IDOS method. Therefore, the result of SDOS method and IDOS method are quite different and thus unrealistic haze correction should be occurred if SDOS method is used without considering the principle of relative scattering of atmosphere. The NDVI images (Figure 3.) have shown clear improvement after applying ATCOR2 method using ERDAS Imagine.

5. Conclusion

The atmospheric haze correction methods have applied to original data in DN counts. However, normalizing the predicted haze values for gain and offset allows the corrections to be applied without converting entire image's DNs into radiance values (Chavez 1988). The correction of atmospheric scattering is very important, especially for the shorter visible wavelength bands because the path radiance has serious effects on them (Lu et al. 2002). The Raipur city has polluted urban area hence the effects of atmospheric haze plays dominant role on the visible bands of remotely sensed image (IRS-IC, LIIS-III, Multispectral image, 20th Feb. 2001) which was unable to produce scene reality for the urban land use mapping and change detection analysis. In this regards, IDOS method was used to produce realistic results based on very clear RSM than SDOS method. Thus, better result has been achieved using ATCOR2 as compared to SDOS method and IDOS method. Therefore, ATCOR2 model has been suggested for the better atmospheric correction of the satellite imageries.

Acknowledgments:

This work is a part of PhD thesis funded by the UGC, New Delhi (No.F.40-114(C/M)/2009 (SA-III/MANF), Dated: December 2010). We are grateful to the Editor in Chief of the journal and volunteer reviewers for their constructive suggestions and comments.

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