MAPPING OF TREE COVER IN URBAN AREA USING DIFFERENT IMAGE FUSION TECHNIQUES

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Abstract:

Tree cover in urban area is of great importance in urban ecosystem. It's play vital roles in enhancing landscape aesthetics, improving water and air quality, providing wildlife habitat, reducing pollution, moderating heat energy, reducing storm, water runoff, and providing other amenities. Hence, urban forest management plays an important role in worldwide. Traditional urban forest m resolution satellite data and its potentials are new tools for managing and mapping tree/ forest covered area. Remote sensing offered a faster, repeatable, objective, cost effective and efficient way to monitor urban forest dynamics at the landscape level. Quickbird satellite data is quickly becoming the best choice for high-resolution mapping. The present study demonstrates the use of spatially enhanced high resolution Quickbird satellite data for estimation of tree cover in urban area in part of Lucknow city. The spatial enhancement of different spatial data sets is often used in digital image processing to improve the visual and analytical quality of the data. The spatial image enhancement technique combines the spectral and high spatial resolution information from two different sensors into one image, which has both spectral and high spatial resolution. In order to improve the spatial resolution, the efficiency of six different spatial enhancement techniques viz. Principal Component, Multiplicative, Modified IHS, HPF, Ehlers Fusion and Brovey Transform with standard deviation 24.53, 20571.15, 46.07, 21.29, 33.50 and 6.84 respectively were examined and evaluated. The Modified IHS spatial enhancement technique with higher standard deviation showing overall best result in compare to others. The Modified IHS spatially enhanced image further used in the urban tree cover estimation. Urban area was masked and extracted the area of interest. The model was developed on the basis of DN value of image those having tree covers and accordingly tree cover was estimated. The urban tree cover is occupies an area of 48.38 ha which is 12% of total geographical area. The information generated in the present study could be used as an important input in the urban forest management programme.

Keywords: Remote Sensing, Mean, Standard Deviation, IHS, HPF, DN, Urban Tree Cover.

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Introduction:

Trees planted in urban settings are described as an urban forest, and they are an important part of the urban ecosystem[1]. Urban trees play an important role in reducing atmospheric CO_2 through assimilation. They can also reduce fossil fuel usage through the processes of transpiration, shading, and the blocking of winds[2]. By reducing the energy usage of man-made structures, carbon emission from power plants also is reduced. Therefore, the quantification of urban tree carbon storage can lead to a better understanding of the relationship between urban trees in global carbon accounting for greenhouse gas emissions and improved urban planning and management. Urban forests play important roles in enhancing landscape aesthetics, improving water and air quality, providing wildlife with habitat, reducing pollution, moderating the urban energy budget, reducing air storm, water runoff, and providing other amenities[3, 4, 5]. It can also lead to improved human and environmental health.

Traditionally, forest management data have been obtained by field sampling and visual interpretation of aerial photos. These methods are expensive, generally labour-intensive and time consuming. Besides, they monitor only a fraction of the area of interest. Monitoring forested areas using digital remote sensing technique offers a faster, repeatable, objective, and efficient way to monitor urban forest dynamics at the landscape level. Additionally, image-based methods can potentially enable mapping of larger areas using the increasing number of temporal databases of satellite imagery.

Digital images taken by space-borne sensors are very frequently used in monitoring forested areas. The increasing applications are due to the availability of high quality images for a reasonable price and improved computation power. Nowadays there is a wide range of systems that provide images in digital format, and their interpretation into terrestrial attributes is very dependent on their spatial and spectral resolution. As a result of the demand for higher classification accuracy and the need in enhanced positioning precision there is always a need to improve the spectral and spatial resolution of remotely sensed imagery. For most of the systems, panchromatic images typically have higher resolution, while multispectral images offer information in several spectral channels. Resolution merge allows us to combine advantages of both kinds of images by merging them into one.

In this research images with high spatial resolution and spectral (Panchromatic and Multispectral) were fused for urban forest mapping through digital analysis and modelling. Another objective was to get best enhanced merged image for the visual interpretation or digital analysis by comparing the results obtained through different merging techniques. In the present study, efficiency of six different merging techniques (Principal Component, Multiplicative, Modified IHS, HPF, Ehlers fusion and Brovey Transform) is examined, in order to improve the spatial resolution of high resolution panchromatic image with multispectral image of Quickbird data.

Study Area:

The study area covers part of Lucknow city of Uttar Pradesh having an area of 403.28 ha and lies between $26^0 52' 25''$ to $26^0 53' 18''$ N latitude $80^0 52' 14''$ to $80^0 54' 38''$ E longitude. Quickbird satellite images acquired with a panchromatic and multispectral having 0.6 m and 1.0 m spatial resolution respectively on 02 September, 2008 were used to merge by various image fusion techniques and evaluate spatial image enhancement technique, among the best enhanced image was further used for urban tree cover estimation. Digital image proceeding, digital analysis and modelling for tree cover estimation were done using Erdas Imagine 9.1 software. Survey of India topographical maps were also referred in ground truth.

Methodology:

Geometric correction

Remote sensing data, directly acquired from the satellites may contain errors such as instrument error, noise, and geometric distortion. In a pre-processing stage, it is necessary to correct the image mostly if we need the same coordinates and projection on the based maps[5]. Even though acquired Quickbird data is geometrically correct but some geometric distortion is retained in it. So that several well distributed ground control points (GCPs) obtained from field coordinates recorded through GPS were used to calculate the geometric transform. Image rectification and projection was performed through polynomial and cubic convolution resampling methods with RMSE was less than 0.5 on the above mentioned images using Erdas Imagine 9.1 software. The coordinate system assigned to the geo reference had UTM projection, correspond to zone 44; the datum is the WGS 1984.

Image Fusion

Image Fusion is a tool for integrating a high resolution panchromatic image with a multispectral image, in which the resulting fused image contains both the high resolution spatial information of the panchromatic image and the colour information of the multispectral image. In this study the efficiency of six different spatial enhancement techniques viz. Principal Component, Multiplicative, Modified IHS, HPF, Ehlers Fusion and Brovey Transform were examined and evaluated.

Figure 1 show various steps involved in image fusion using different merging techniques. The essential steps in this study include image rectification, registration, resampling and fusion using different merging techniques.

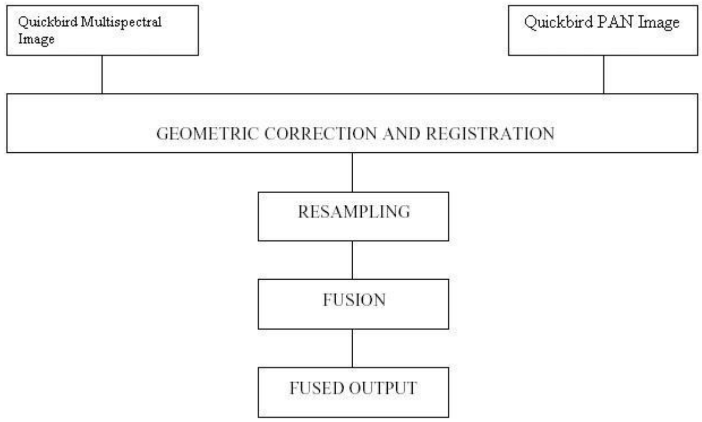

Figure 1 Flowchart depicts the methodology adopted for multi sensor image fusion.

1. **Principal Component**

This method calculates principal components, remaps the high resolution image into the data range of PC-1 and substitutes it for PC-1, then applies an inverse principal components transformation. The Principal Component method is best used in applications that require the original radiometry of the input multispectral image to be maintained as closely as possible in the output file. In this method scales the high resolution data set to the same data range as PC-1, before the Inverse Principal Component calculation is applied, the band histograms of the output file closely resemble those of the input multispectral image[6]. This result in the transformation of a multispectral data set into an image of higher spatial resolution[7].

2. **Multiplicative**

This method applies a simple multiplicative algorithm which integrates the two raster images. It is computationally simple it is generally the fastest method and requires the least system resources. However, the resulting merged image does not retain the radiometry of the input multispectral image. Instead, the intensity component is increased[6]. Multiplicative approach was based on the following simple arithmetic integration of the two raster sets:

DNB1 x DN high res. Image = DNB1_new
DNB2 x DN high res. Image = DNB2_new
DNB3 x DN high res. Image = DNB3_new

Where, DN is digital number, B is band, DN high res. Image is Digital number of high resolution image and DNB1_new is Digital number of band 1 merged image.

3. **Brovey Transform**

The Brovey transformation technique uses a mathematical grouping of the colour image and a high resolution image. The Brovey transform is also named as the Energy Subdivision Transform that employs a high resolution image to sharpen a low resolution image. This algorithm is also called as Colour Normalised Transform. The Brovey transform algorithm uses a formula that normalizes multispectral bands used for an RGB display and multiplies the result by high resolution data to add the intensity or the brightness component of the image. This method uses a ratio algorithm to combine the images as shown below[6]:

$[DN_{B1} / DN_{B1} + DN_{B2} + DN_{Bn}] \times [DN_{high\ res.\ image}] = DN_{B1\_new}$
$[DN_{B2} / DN_{B1} + DN_{B2} + DN_{Bn}] \times [DN_{high\ res.\ image}] = DN_{B2\_new}$
etc.
where $_B$ = band

4. **Modified IHS**

The Modified IHS (intensity, hue, saturation) resolution merge function allows you to combine high-resolution panchromatic data with lower resolution multispectral data, resulting in an output with both excellent detail and a realistic representation of original multispectral scene colors. The technique works by assessing the spectral overlap between each multispectral band and the high resolution panchromatic band and weighting the merge based on these relative wavelengths. Therefore, it works best when merging images (and bands) where there is significant overlap of the wavelengths. Although the modified IHS method can only be run on three bands at a time, it is possible to fuse more than three bands through multiple applications. This has been found to work well even when combining bands from the separate applications. The basic idea behind the modified IHS equation is simple; modify the input intensity (panchromatic band) so that it looks more like the intensity of the input multispectral bands. The steps are[8]:

1) **Choose the β coefficients:** β coefficients represent the relative contributions of each portion of the electromagnetic spectrum to the panchromatic (PAN) band. The regression analysis is performed on multispectral (MS) bands vs. the panchromatic band. If the MS and PAN data come from the same sensor, a linear regression is sufficient to derive a good relationship between the two datasets otherwise it may be possible to improve by using higher-order terms.

2) **Choose the α coefficients:** The desired output is equally weighted toward Red (R), Green (G), and Blue (B). In such cases, the α coefficients are equal and given by

$$\alpha = \frac{\sum_m \beta_m \overline{MS}_m}{3\overline{PAN}}.$$

$\overline{MS}_m$ = average of band m; $\overline{PAN}$ = average of panchromatic (PAN) band; β_m = coefficient for band m.

3) **Generate modulation ratio:** Apply an RGB-to-HIS transform on the three MS bands and generate intensity modification ratio:

$$r_1 = \frac{a_r d_r + a_g d_g + a_b d_b}{\sum_m \beta_m d_m}$$

Where, r_I is intensity modification ratio, α_r is numerator coefficient for red DN value, d_r is DN value of band used for red output, α_g is numerator coefficient for green DN value, d_g is DN value of band used for green output, α_b is numerator coefficient for blue DN value, d_b is DN value of band used for blue output, β_m is denominator coefficient for DN value of band m, d_m is DN value of band m and bands m represents all bands that cover the spectral range of the panchromatic band.

4) **Reverse transformation:** Multiply the modification ratio r_1 by the PAN band. Transform the modified HIS data back to RGB space to generate the final product using the modified intensity.

5. **High Pass Filter (HPF)**

The HPF resolution merge function allows you to combine high-resolution panchromatic data with lower resolution multispectral data, resulting in an output with both excellent detail and a realistic representation of original multispectral scene colors. The process involves a convolution using a High Pass Filter (HPF) on the high resolution data, then combining this with the lower resolution multispectral data. Pixel sizes from Image files were read the ratio of multispectral cell size to high-resolution cell size was calculated. High-pass filters the high spatial resolution image. Multi-spectral image was resampled to the pixel size of the high-pass image. HPF image was added to each multi-spectral band. New multi-spectral image to match the mean and standard deviation of the original (input) multi-spectral image was stretched.

6. **Ehlers Fusion**

The algorithm was developed by Mr Manfred Ehlers from Onasbruck University, Germany, and it is called Ehlers fusion. The Ehlers fusion is based on an IHS transform coupled with a Fourier domain filtering. This technique is extended to include more than 3 bands by using multiple IHS transforms until the number of bands is exhausted. A subsequent Fourier transform of the intensity component and the panchromatic image allows an adaptive filter design in the frequency domain. Using fast Fourier transform (FFT) techniques, the spatial components to be enhanced or suppressed can be directly accessed. The intensity spectrum is filtered with a low pass filter (LP) whereas the panchromatic spectrum is filtered with an inverse high pass filter (HP). After filtering, the images are transformed back into the spatial domain with an inverse FFT and added together to form a fused intensity component with the low-frequency information from the low resolution multispectral image and the high-frequency information from the high resolution image. This new intensity component and the original hue and saturation components of the multispectral image form a new HIS image. As the last step, an inverse IHS transformation produces a fused RGB image. These steps can be repeated with successive 3-band selections until all bands are fused with the panchromatic image[9].

Tree Cover Estimation

The tree cover estimation was performed on merged image of Quickbird satellite data. The area of interest having urban area was masked and DN value of urban tree cover in each band was analysed and recorded. The urban tree cover was classified into three classes by slicing of DN value tree cover. Slicing was done on the basis of commission and omission of tree cover DN value, accordingly different ranges of DN value of each band gives in model to generate tree cover classes. Model was run on the merged data for estimation of urban tree cover using Erdas Imagine 9.1 software as shown in figure 2.

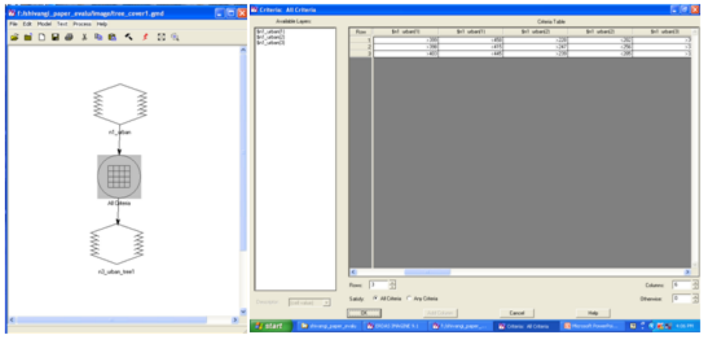

Figure 2 Showing Model for Estimation of Urban Tree Cover

Results:

Evaluation of Spatial Image Enhancement Techniques

The spatial image enhancement technique combines the spectral and high spatial resolution information from two different sensors into one image, which has both spectral and high spatial resolution to improve classification accuracy, image sharpening, enhancement of features etc. The Quickbird panchromatic and multispectral image was merged using different techniques such as Principle Component, Multiplicative, Brovey Transform, Modified IHS, High Pass Filter (HPF) and Ehlers fusion. The resulting images obtained are shown in Figure 3. The statistical parameters are viz. minimum, maximum, mean, median, mode and standard deviation of fused images obtained from each approach are presented in Table 1. The statistics of six different spatial enhancement techniques viz. Principal Component, Multiplicative, Modified IHS, HPF, Ehlers Fusion and Brovey Transform with standard deviation 24.53, 20571.15, 46.07, 21.29, 33.50 and 6.84 respectively were examined. The Modified IHS among the spatial enhancement technique having 2nd highest standard deviation.

The visual analysis of images in different spatial enhancement techniques, the Principle Component was given red colour of water bodies, urban area and vegetation cover. In the Brovey Transform, HPF and Ehlers fusion were given black colour of water bodies but distinguishable in tree cover, settlement and agriculture area. In the HPF image, linear features became sharp and bright in compare to others merging techniques. In modified IHS, showing overall best result in compare to others with best representation of natural and man-made features.

The modified IHS method is a vast improvement over traditional IHS for fusing satellite imagery that differs noticeably in spectral response. It can be used to improve and enhance the utility of high-resolution imagery from various satellites. The method is computationally efficient and can be programmed into most commercial image processing packages. Carper *et al*. (1990) used intensity-hue- saturation transformations for merging SPOT panchromatic and multispectral image data[10]. Intensity-Hue- Saturation transformation model is one of most often used in merging multi-sensor/ multi-resolution data[11].

The comparison and evaluation the statistical results and visual analysis of images obtained in different techniques it's found modified IHS was the best merging technique. The Modified IHS image with higher standard deviation and best representation of natural and man-made features was further used in the urban tree cover estimation.

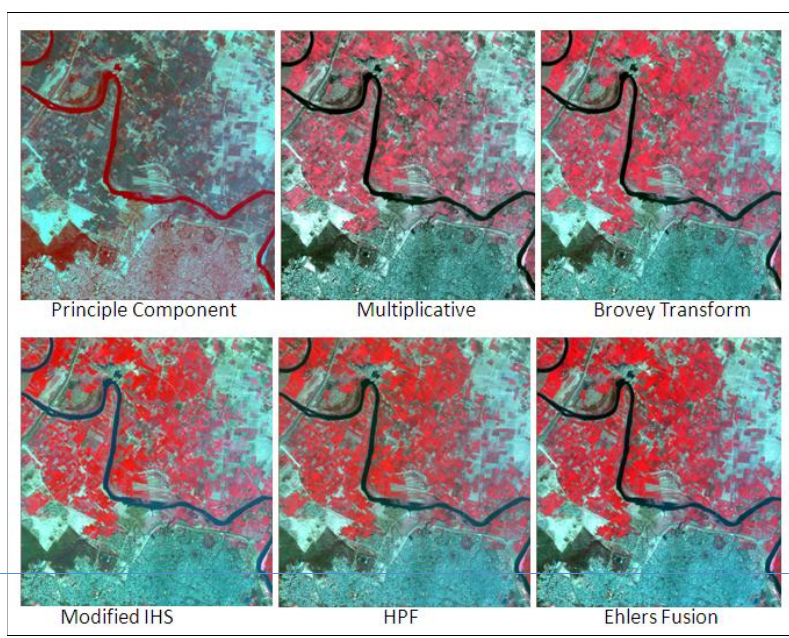

Figure 3 Results of Different Resolution Merging Technique

Table 1 Statistics of Different Spatial Enhancement Techniques

Merging Tech.	Min	Max	Mean	Median	Mode	Std. Dev.
Principle Comp.	-66	526	288.012	285.5	280.88	24.53
Multiplicative	64052	4.34E+05	123494.464	1.2189e+005	1,1755e+005	20571.15
Brovey Trans.	54.421	165.37	81.864	81.291	79.557	6.840
Modified HIS	240	804	438.618	433.88	433.88	46.07
High Pass Filter	1	557	308	305.06	289.86	21.29
Ehlers Fusion	3	476	191.491	189.61	189.61	33.50

Estimation of Tree Cover in Urban Area

The urban trees and other vegetation can mitigate the urban heat island effect because they shade buildings, intercept solar radiation, and cool the air by evapotranspiration. By cooling, trees reduce evaporative emissions from vehicles and other fuel storage, and by cooling homes and offices, trees reduce power generation emissions. Trees and other vegetation also can improve air quality as well as provide other amenity and aesthetic benefits such as shade and beauty.

Mapping of tree cover is usually based on field survey and aerial photo interpretation[12]. The field measurements of tree cover are time consuming and expensive and usually cannot provide complete coverage of large area. So that high spatial resolution Modified IHS merged Quickbird satellite data was used for identifying, extracting and mapping in urban tree cover. The part of modified IHS merged Quickbird satellite image acquired on 02.09.2008 is represented in Figure 4.

The DN value of tree cover in each band of Modified IHS merged Quickbird satellite data was analysed and recorded which is given in Table 2. The urban tree cover was classified into three classes by slicing of DN value tree cover. Slicing was done on the basis of commission and omission of tree cover DN value, accordingly different ranges of DN value of each band given in model to generate tree cover classes. The ranges of DN value in each urban tree cover classes and in each band are given in Table 3. The area statistics of urban tree cover classes is given in Tables 4. The total urban tree cover is estimated an area of 48.38 ha which is 12% of total geographical area. The part of map of urban tree cover generated by modelling is represented in Figure 5.

Figure 4: Modified IHS Merged Quickbird Satellite Data Acquired on 02.09.2008

Table 2 DN Value of Merged Data for Tree Cover Estimation in Urban Area

Sl. No.	Band 1	Band 2	Band 3
1.	399	229	476
2.	403	268	460
3.	410	252	457
4.	410	256	492
5.	412	252	521
6.	414	253	445
7.	416	246	355
8.	417	246	499
9.	418	249	529
10.	420	252	457
11.	420	274	322
12.	423	253	384
13.	423	262	400
14.	424	235	507
15.	425	261	459
16.	426	261	531
17.	427	263	410
18.	428	258	446
19.	431	233	510
20.	431	259	332
21.	434	248	385
22.	434	268	505
23.	435	269	445
24.	437	258	506
25.	437	267	501
26.	438	279	423
27.	439	278	430
28.	443	274	401
29.	444	273	355
30.	446	284	456
31.	448	270	429
32.	448	279	461
33.	450	269	508
34.	451	276	464
35.	457	271	469

Table 3 Urban Tree Cover Class wise DN Value Range in Bands

Sl.No.	Urban Tree cover Classes	Band1	Band2	band3
1	1	400 - 457	229 - 281	392 – 531
2	2	399 - 414	248 - 255	334 – 357
3	3	404 - 444	240 - 284	322 – 384

Table 4 Area Statistics of Urban Tree Cover

Sl.No.	Urban Tree cover Classes	Area (ha)	Area in Present
1.	1	12.52	3.10
2.	2	0.94	0.23
3.	3	34.92	8.66
	Total	**48.38**	**12.00**

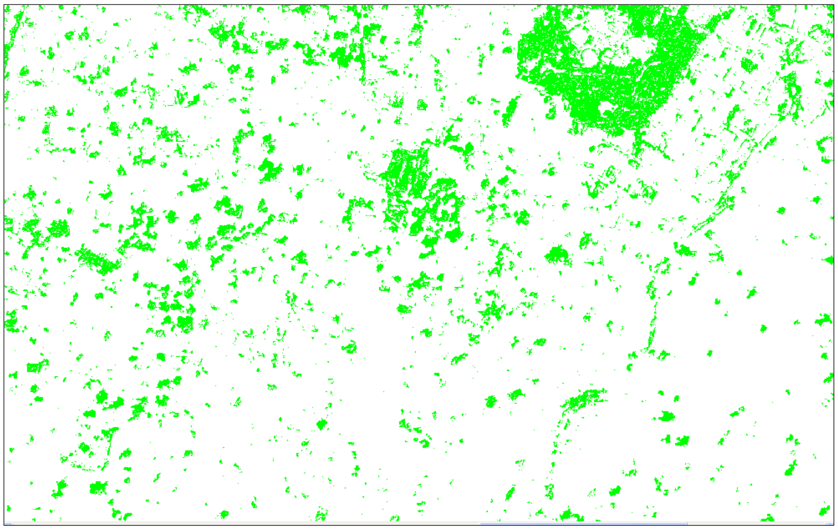

Figure 5 Urban Tree Cover on 02.09.2008

Conclusion:

This study proves the importance of spatial enhancement techniques and evaluation methods that should be consistent and the necessity of a combined method for a quantitative and qualitative assessment of spatial improvement and spectral preservation. The Modified HIS spatial enhancement technique gives best result in compare to others spatial enhancement techniques with best representation of natural and man-made features. It's suited for spatial merging of high resolution panchromatic and multispectral Quickbird images. Therefore it could be used in digital image analysis, visual interpretation, image mapping and photogrammetric purposes.

The urban tree cover estimated and mapped on the basis of DN value through the modeling on spatially enhanced image. This image processing techniques is quiet faster and resulted in better identifying, extracting and mapping of urban tree cover in compare to standard image processing/ image classification technique or visual interpretation. It could be used in the urban forest monitoring and management programme. The information generated of urban tree cover could also be used an important input as base information for urban forest programme.

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