Abstract— Nowadays Spectral Distortion is one of the most important problem in the fusion of remote sensing images. Remote Sensing systems, deployed on satellites, which provides a repetitive and consistent view of the earth. The fusion of a PAN image that has high spatial resolution but low spectral resolutions with Multispectral (MS) image is the key issue in many remote sensing applications that require both high spatial and high spectral resolutions. Today, many image fusion techniques have been developed. The Intensity-Hue-Saturation (IHS)-based methods are well known in quick image fusing. But, in vegetated areas most of these processes produce color distortion due to the unnatural spectral response of IKONOS sensors. In order to correct the unnatural color appearance many recent methods make use of the enhancement and extraction of vegetation. This enhancement and extraction is accomplished using Vegetation Indexes (VIs). A new fusion technique is proposed to produce the images with natural colors. Moreover, in this technique, a High-Resolution Normalized Difference Vegetation Index (HRNDVI) is also proposed and used in delineating and extracting the vegetation. This new approach provides a very good results in terms of objective and quality measures. Visual analysis of the proposed approach improves the fusion quality of the images by enhancing and extracting the vegetated zones.

Index Terms—Image Fusion, Intensity-Hue-Saturation (IHS) transform, Vegetation Enhancement and Extraction, Vegetation Index (VI).

I. INTRODUCTION

Earth observation satellites which provides both Multispectral (MS) and Panchromatic (PAN) data that has different spatial, spectral, temporal, and radiometric resolutions. The fusion of a PAN image with MS images is a key issue in many remote sensing applications that requires both high spatial and high spectral resolutions. The fused image provides the feature enhancement and increase the classification accuracy [14]. There is an increasing use of image processing techniques to fuse the MS and PAN images.

These image processing techniques are known as Pan-Sharpening or Resolution Fusion techniques. Today the most widely used approach for fusing the images is the Intensity-Hue-Saturation (IHS) approach [1]. When exactly three MS bands are concerned this technique is suitable. When more than three bands are available, then use all of the MS bands located within the PAN band, particularly the Near Infra Red (NIR) band. In this context, the authors defines the Fast IHS (FIHS) transform method for three bands and a generalized IHS (GIHS) transform method for four bands by including the NIR band in the computation of the Intensity Component (I) [2]. In order to improve the fusion based on various IHS transform methods, like those presented in [3] and [4] and the spectral adjusted IHS developed in [2], were proposed. Moreover, in vegetation visualization applications, recent methods make use of the enhancement and extraction of vegetation to improve the color quality [5], [6], [7].

Vegetation is considered as the key component of the urban environment. However, urban environment is complex and very different from rural and natural environment [8]. This enhancement is applied in the vegetation in urban areas, which are delimited and extracted using a Vegetation Index (VI). The contribution of this paper is to define a new fusion algorithm that can preserve the PAN spatial and MS spectral qualities and that can produce the best possible images for vegetation visualization and extraction. It is accomplished in two steps. The first one is a fusion process, based on the GIHS method with spectral adjustment [13]. The second step is a vegetation enhancement process, where the vegetated areas are boosted. And the last step is the vegetation extraction using extended Tasseled Cap Transformation (TCT). Moreover, a High-Resolution version of the Normalized Difference Vegetation Index (HRNDVI) is proposed to identify the areas to be enhanced and extracted. In this paper, we aim to develop a new method for vegetation extraction using IKONOS imagery. This method is a good solution when the urban areas are considered.

II. RELATED WORKS

A. A New Intensity-Hue-Saturation Fusion Technique with Color Distortion Reduction for IKONOS Imagery

When the IHS method is used for IKONOS imagery, there is a significant color distortion, due to the range of
wavelengths in an IKONOS PAN image. The gray values of PAN images in the green vegetated regions are far larger than the grey values of intensity (I) and that vegetation appears relatively high reflectance in Near Infrared (NIR) and PAN bands. A new technique known as Normalized Difference Vegetation Index (NDVI) to identify the vegetation area and then enhances it in the green (G) band by using the red (R) and the near infrared (NIR) bands [5]. To obtain an intensity image with the grey values comparable to PAN image’s gray value. So there by the color distortion in the fused image is reduced. Visual and statistical analyses prove that the concept is promising, and it significantly improves the fusion quality compared to other conventional IHS techniques. The advantages of this method are the better color quality in the green vegetation region and improves the fusion quality of the images. The disadvantages of this method are no vegetation enhancement and false vegetation detection.

B. A Fast Intensity Hue Saturation (IHS) Fusion Technique with Spectral Adjustment for IKONOS Imagery

For various image fusion methods, Intensity–Hue–Saturation (IHS) technique is capable of quickly merging the massive volumes of data. For IKONOS imagery, IHS can yield satisfactory spatial enhancement but introduce spectral distortion, appearing as a change in colors between compositions of resampled and fused multispectral bands. To solve this problem, a new method called Fast IHS fusion technique with spectral adjustment is presented [2]. This new approach can provide better performance than the original IHS method, both in processing speed and image quality.

C. An Improved Intensity Hue Saturation (IHS) for IKONOS Image Fusion

A useful technique in various applications of remote sensing, which involves the fusion of panchromatic (PAN) and MultiSpectral (MS) satellite images. Recently, Tu et al. introduced a new method ie, Fast Intensity-Hue-Saturation (FIHS) method of image fusion with spectral adjustment for IKONOS imagery [6]. Aside from its fast computing capability for fusing images, this method can reduce the color distortion problem inherently in IHS-like fusion. Because the spectral response of an IKONOS PAN image does not cover the spectral response of the blue band and green band, Tu et al. used the FIHS method in a special way: that is, they applied a modified intensity image with weighting parameters of 0.75 for the green band and 0.25 for the blue band. However, the response of the IKONOS PAN image extends far beyond the Near Infra Red (NIR) band, additional spectral adjustment of the NIR band is desirable. Therefore an FIHS method is proposed that will incorporates the spectral adjustment of all IKONOS MS bands. Even though the eFIHS SA method gives a satisfactory result for IKONOS image fusion, we can achieve the better results through the FIHS method in which additional spectral adjustment is considered for all IKONOS MS bands. Images fused by the proposed method has the better spectral quality than the images fused by the eFIHS SA method. The spectral quality of the images fused by this method is as good as the spectral quality of images fused by the wavelet based method.

III. PROPOSED METHOD

This paper aims to reduce the spectral distortion in remote sensing images and vegetation enhancement and extraction in IKONOS imagery. Extracting RGB components from the original image. Convert the RGB color space to IHS color space. Fast Intensity Hue Saturation (FIHS) method is used to fuse the images. The fused image is obtained after the FIHS fusion provides the full details of PAN image but introduces the color distortions. In order to reduce this distortion, one must generate an intensity component I, which must be as close as possible to the PAN image. When the NIR band is available, a possible solution is to define a GIHS transform by including the response of the NIR band into the intensity component; then generate the fused band and obtain the fused image. After obtaining the fused image, the next step is to enhance the vegetation area. In this the vegetation areas are boosted by using NDVI,HRNDVI methods. The last step is vegetation extraction process; where a fixed-threshold Vegetation Index (VTMap) based on the extended Tasseled Cap transformation (TCT). Then it is applied to extract the vegetation from the fused images [9]. TCT aimed at analyzing the vegetation.

- Extracting R G B Components
  First step is to extract the R,G,B components from the original image. The IHS transform is used as an image fusion technique to develop the complementary nature of multisensor image data [2]. Before conducting an IHS fusion, the color image should be registered with the high-resolution PAN image and it should be resampled to the same pixel size with the PAN image [10].

- Convert RGB to IHS
  The three bands (R, G, and B) of a color image is to be transformed from the RGB space into the IHS space. In general, the IHS fusion consists of the following steps [11].
  1. Upsample the RGB images to the same pixel size of the PAN image; and then convert them to the IHS components.
  2. Replace the intensity component I with the coregistered PAN image.
  3. Transform the H, S, and replaced PAN image back to the RGB space by the inverse IHS transform.

- FIHS Transform
  In FIHS Transform three bands are used ie, R,G, B bands. The authors in [11] present a computationally efficient method (FIHS); in this the fused image can be obtained simply and directly from the original image. The fused image obtained after the FIHS fusion provides the full details of PAN image but it introduces some color distortions.

- Calculate Intensity Component
  In order to decrease the distortion, one must create an Intensity Component \( I \) [13] which must be as close as possible to the PAN image.

\[
I = \frac{(2 \times G + B)}{3}
\]
GIHS Transform

When the NIR band is available, the possible solution is to define a GIHS transform by including the response of the NIR band into the intensity component. In this case, I is obtained by weighing each band with a set of coefficients. The choice of these weights can be related to the spectral responses of the PAN and MS bands by considering the spectral characteristics of the sensors. The GIHS transform method is used for four bands by including the NIR band in the computation of the Intensity component (I). For this, I is obtained by weighing each band with a set of coefficients. The choice of these weights can be related to the spectral responses of the PAN and MS bands and by considering the spectral characteristics of the IKONOS sensors [13].

\[ I = w_R R + w_G G + w_B B + w_{NIR}NIR \neq PAN \]  

(2)

Where \( w_R, w_G, w_B \) are the weighing coefficients.

Fused Band

While using the GIHS method in [3], Choi projected a new IHS approach for image fusion with an adjustment parameter which reflects the spectral characteristics of the sensors. In the calculation of the I component, by using the spectral adjustment he used it to analyze each fused band. His proposed method [13] is expressed as:

\[ Fused \ Band = Band + \delta \Delta = PAN - I \]  

(3)

Final Fused Image

In a general expression [13] form, let

\[ \alpha = (t - 1)/t \]  

(4)

Where \( t \) is a tradeoff parameter. Then,

\[ Fused \ Band = Band + \alpha \delta \Delta = PAN - I \]  

(5)

Where \( \delta \) is the spectral distortion of the fused image.

The tradeoff parameter \( \alpha \) has suitable value for IKONOS images was found to be equal to four; therefore, \( \alpha = 3/4 \). In IKONOS, the vegetation appears comparatively low reflectance in the RGB bands because the vegetation regions of the MS images are much darker. Three different tradeoff parameters ( \( t_1 = 2.5, t_2 = 3.5, t_3 = 2.0 \) ) are used to overcome this problem [13].

NDVI with 0.15 threshold

For a variety of remote sensing applications the NDVI mostly used VI. It is rarely used to generate high-resolution vegetation maps. In some applications, the IKONOS imagery can be used to map a vegetation cover for remote sensing images [12]. The IKONOS PAN images provide more details of buildings and individual trees, because the vegetation appears with a relatively low reflectance in the RGB bands therefore the vegetation zones of the MS images are much darker. When the enhancement is to be done the VI is used inorder to delineate the vegetated area. A new technique for IKONOS image fusion was proposed in [6], and the technique consists of a hue spectral adjustment method integrated into an IHS transformation. The idea is to boost the G band in order to minimize the difference between the PAN image and the I component [5]. The vegetated area is detected by using the NDVI and then boosting will be applied in that area. A VI was proposed [7] and it takes advantage of the high spatial resolution information of the PAN images. The VI is expressed as[13]:

\[ VI = PAN - I_G \neq PAN + I_G \]  

(6)

Instead of the NIR and R bands it uses the PAN image and the J component and it contains much spatial details provided by the PAN image. By, applying the VI on the images, which does not give up the expected good results. Some confusion is always observed in distinguishing between vegetation and shadows because of using several threshold values. In order to overcome this confusion a new NDVI is proposed using the fused bands. By using the fused low-resolution R and NIR bands with the high-resolution PAN image a high resolution vegetation map can be generated. This vegetation index will be denoted as HRNDVI for high resolution NDVI [13]. As the conservative NDVI is defined by,

\[ NDVI = (NIR - R)/(NIR + R) \]  

(7)

HRNDVI with 0.3 threshold

To detect the vegetated area [14], the following two ways are identified:

1) If VI is considered, then

\[ \delta_2 = \begin{cases} \delta_2 & VI \leq 0 \\ k\delta_2 & VI > 0 \end{cases} \]  

(8)

2) If NDVI is used, then

\[ \delta_3 = \begin{cases} \delta_3 & NDVI \leq 0 \\ k\delta_3 & NDVI > 0 \end{cases} \]  

(9)

Where \( k \) is the constant. Then the new index is defined by [13] as:

\[ HRNDVI = \frac{(Fused \ NIR - Fused \ NIR)}{(Fused \ NIR + Fused \ NIR)} \]  

(10)

Usually, the fused bands R and NIR contains the PAN image, which spatially improves the proposed HRNDVI. The VI and HRNDVI gives more details than the conventional NDVI. They have high frequencies and better spatial resolution compared to NDVI. The HRNDVI appears to be a solution where the spatial information of the PAN image is used without any confusion in vegetation detection [13]. The contribution of the PAN image in detecting vegetation is clearly in the VI and HRNDVI maps. These two VI conserves more detailed vegetation areas than the conventional NDVI. The HRNDVI is a good result in introducing the spatial resolution in the calculation of the NDVI, and it guarantees less confusion in the vegetation detection process.
Extracting the Vegetation

The vegetation extraction for IKONOS imagery is an important application, which is used to monitor crops, in terms of their identity and stages of their growth. In the vegetation enhancement, the vegetated areas are delineated. A fixed threshold approach generating high resolution vegetation maps for IKONOS imagery has been proposed in [9]. In this technique an extended Tasseled Cap Transformation (TCT) method is used to produce the vegetation map; then it is applied to extract vegetation from the fused images. After an Intensity-Hue-Saturation (IHS) based fusion method [2], a high resolution version of this map is obtained. The Vegetation Index Tasseled Cap (VITC) [13] was derived as:

\[ V_{\text{TCT}} = \frac{1}{2}T_C - \frac{1}{2}T_C - \frac{1}{2}T_C \]

(11)

where \( T_{C_1}, T_{C_2}, T_{C_3} \) are IKONOS TCT coefficients.

The vegetation map VTCmap is produced by a fixed threshold approach:

\[ V_{\text{VTCmap}} = \begin{cases} V_{\text{TCT}}, & \text{Where } V_{\text{TCT}} \geq 0 \\ 0, & \text{Where } V_{\text{TCT}} < 0 \end{cases} \]

(12)

In the vegetation extraction, only the G band is enhanced in the vegetated areas, and to extract the vegetation using IKONOS imagery TCT method is used. This method is a good solution when an urban case is considered; it provides a new data source for monitoring agricultural production and for giving information for the development of crops during the growing season.

IV. RESULTS AND IMPLEMENTATIONS

The below figures shows some experimental results. The proposed method performs well in the remote sensing images. This method reduces color distortion in the vegetated areas and provides natural color. This method can be focused on fusion process and for vegetation visualization and extraction applications. Fig. 1(a) shows the original image. The first step is to extract R, G, B components. Fig. 1(b),1(c),1(d) shows the extraction of R, G, B components.

![Fig.1(a)Original Image](image1.png)  ![Fig.1(b)Extracted R Component](image2.png)

After extracting the R,G,B components from the original image the next step to fuse the images by using IHS fusion technique. For using three bands (R,G,B), Fast IHS method is suitable. The FIHS fusion provides the full details of PAN image but it introduces some color distortions. To avoid the color distortion a new method called Generalized IHS is used. This method gives a high quality image with natural color. Fig. 2(a) FIHS method and Fig. 2(b) GIHS method.

![Fig.1(c) Extracted G Component](image3.png)  ![Fig.1(d) Extracted B Component](image4.png)

Next step is to enhance the vegetation by using NDVI and HRNDVI. NDVI performs some confusion in vegetation detection. To reduce this confusion and high light the vegetation areas by using HRNDVI. Fig. 4(a) shows NDVI and Fig. 4(b) shows HRNDVI.

![Fig.2(a) FIHS Method](image5.png)  ![Fig.2(b) GIHS Method](image6.png)

To provide more accurate result than NDVI and HRNDVI a fixed threshold approach is used. This approach is based on
Tasseled Cap Transformation (TCT) method. It is used for analyzing vegetation. This has been applied in fused images for extracting the vegetation. Fig. 5(a) shows the original image and Fig. 5(b) shows the extracted image. It gives details of individual trees and monitoring the agriculture.

![Fig. 5(a) Original Image](image1) ![Fig. 5(b) Extracted Image](image2)

V. CONCLUSION

A new method has been presented for image fusion, vegetation visualization and extraction. The image fusion is based on the GIHS method, with some G and B bands enhancement in the vegetated zones. A modified Vegetation Index (HRNDVI) has been proposed for the better vegetation detection. This new technique has been proven to be efficient in the process of PAN-sharpening IKONOS images. Tasseled Cap Transformation (TCT) method is used for extracting the vegetation. This method performs well on the images that contains mixed or more vegetated areas. The results were compared with other existing approaches. This comparison clearly shows that the new method gives very good visual results and produces nondistorted natural image colors. The fixed threshold approach helps in generating highresolution vegetation maps for IKONOS imagery Moreover, this new method is used for agricultural monitoring and also for giving information for the development of crops during the growing season.

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Ms. Donamol Joseph completed her B.Tech in Information Technology with first class in 2010 from Amal Jyothi College of Engineering, India. Currently she is pursuing M.Tech (Multimedia Technology) in the department of Information Technology, Karunya University, Coimbatore. Her research interest is Image Processing.

Ms. T. Jemima Jebaseeli completed her M.Tech in Computer and Information Technology with Distinction in 2006 from Manonmaniam Sundaranar University, India. Her research interest is Image Fusion and Content Based Image Retrieval, Super Resolution Images.