

# Fusion Technique to Extract Detail Information from Moderate Resolution Data for Global Scale Image Map Production

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**Abstract - The Global Irrigated Area mapping project at IWMI addresses the need to develop improved regional or global image products that incorporate spatial and temporal heterogeneity of agriculture. Fusion of freely available high temporal resolution MODIS composite image and high spatial resolution GeoCover Landsat TM mosaic is an appropriate approach to monitor temporal and spatial variability in agriculture at global scale. Methodologies were developed using the techniques of IHS color transformation and Principal Component Analysis to produce global image fusion products. In these processes, the spectral characteristics of the original MODIS multi-spectral image are maintained. In effect one can clearly identify the textural and structural features of land cover as well as the vegetation cover at the period of MODIS data acquisition. Moreover it improves classification accuracy and spatial disaggregation.**

**Keywords:** Global mapping, Image fusion, IHS, PCA, MODIS composite, GeoCover mosaic.

## 1. INTRODUCTION

The statistics on irrigated area are presumed to be very accurate in the case of a country like USA and to be rather speculative in the case of a developing country with substantial informal irrigation. FAO (Aquastat) has collated much of the existing statistics on global irrigated area and collaborated with the University of Kassel to produce a map showing the extent of equipped irrigated areas on a global basis (Doll and Siebert, 1999). The FAO statistics collate equipped area, which in some countries ignores the informal sector. These published statistics are accompanied by data on cropping intensity and pattern. In some countries, reported statistics reflect only the area on which irrigation charges are successfully levied, and may therefore underestimate actual cropped area. In other countries, the extent of equipped area may far exceed the available water supply, and therefore the actual area irrigated should be considerably lower than that reported. No one has a clear idea of the regional and total errors in the estimation of irrigated area. A more detailed explanation of the uncertainties of irrigated area estimation in China is given by Nickum (2003).

Low cost techniques are required, which are of sufficient accuracy to allow correct identification of irrigated area over a range of climatic conditions ranging from clear sky - arid to cloudy tropical and over physical scales from small holder to large contiguous irrigation schemes. Separation of irrigated from non-irrigated agriculture must be achieved with an assessment of annual cropping intensity in the irrigated lands. With a single data set, it is rather difficult to study irrigated area and its dynamic signatures. Therefore, it requires massive amount of expensive remote sensing data. Fortunately

remote sensing data products such as GeoCover Landsat TM mosaics and MODIS composites are freely available.

Data fusion is a very wide domain and Pohl (1996) provide the following definition: "*data fusion combines data from multiple sensors, and related information from associated databases, to achieve improved accuracy and more specific inferences than that could be achieved by the use of single sensor alone*". The purposes of data fusion should be that the information obtained should at least improve image visualization and interpretation. There are several fusion approaches, based on the stage at which the fusion is performed. Pixel based approaches have commonly been used for satellite imagery, where data are merged on a pixel-by-pixel basis. In this study, appropriate pixel-based fusion methods were developed to extract detailed information from multi-temporal MODIS 8-day composite data and GeoCover Landsat TM mosaic data at global scale.

## 2. DATA USED

As the project ultimately has to cover global area, freely available data is used wherever possible in this project. Recently several projects have been launched by different space agencies to provide global product of satellite images for environmental monitoring and change detection.

### 2.1 GeoCover-Ortho Landsat Mosaic

The EarthSat Corporation is producing GeoCover-Ortho Landsat mosaics data for NASA, to create a geodetically accurate digital database of Landsat TM mosaic images covering the entire Earth. GeoCover image mosaics are false-color images created from 12 to 15 Landsat TM images using bands 2, 4 and 7, with the raster cell resolution of 28.5 meters and the horizontal positional accuracy of less than 50 meters. These images are in WGS 84 datum and Universal Transverse Mercator (UTM) projection system. The GeoCover mosaics are segmented into tiles of approximately 250,000 square kilometers. Each tile covers five degrees of latitude in a UTM zone, which is 6 degrees of longitude. These mosaic images are in MrSid compressed image format and can be downloaded via Internet. The images show maximum green area, structural features of the terrain and a detail inventory of manmade features.

### 2.2 MODIS 8-Day Composite

MODIS images are multi-spectral products and are acquired daily. The daily images can be geometrically corrected to approximately 1-2 pixel horizontal accuracy and used for real time applications.

Because of cloud cover (depending on location and season), assessment may be difficult or impossible using single date multi-spectral imagery. Thus images have to be combined with other dates to get a cloud free composite image. During the rainy season, cloud, shadow and other atmospheric influences exist, even in a composite image. NASA has developed 8 day composite images in 7 bands, as cloud free products to monitor the Earth's terrestrial photosynthetic vegetation activity.

### 3. METHODOLOGY

Pohl and Van Gendren (1998) provide a comprehensive review of image fusion techniques. Among those numerous techniques, IHS color transformation and Principal Component Analysis (PCA) techniques were selected to fuse high resolution and medium resolution multi-spectral imageries. As these pixel based fusion techniques require good preparation of data in same coordinate system, equal pixel size and radiometric resolution, the MODIS ISIN tiles were reprojected to UTM projection system and the reflectance values were rescaled to 8 bit. Then the MODIS composite (500m) and the GeoCover mosaic (28.5m) data were resampled to 100m resolution.

#### 3.1 IHS Color Transformation Method

The IHS transformation can effectively separate a RGB (Red, Green, Blue) color image into IHS (Intensity, Hue, Saturation). Intensity (I) refers the total brightness that corresponds to the surface roughness, hue (H) the wavelength contribution and saturation (S) is its purity (Carper et. al., 1990). The detailed steps of the IHS transformation used in this study are given in Figure 1. The most important steps are; (1) Transform a color image (R: SWIR G: NIR B: Green) of GeoCover Landsat TM mosaic from the RGB space to IHS space, (2) Similarly transform a color image (R: SWIR G: NIR B: Green) of MODIS 8 days composite from the RGB space to IHS space, (3) Replace the intensity component of MODIS data by the intensity component of GeoCover data, (4) Reversely transform back to RGB to obtain fused image.

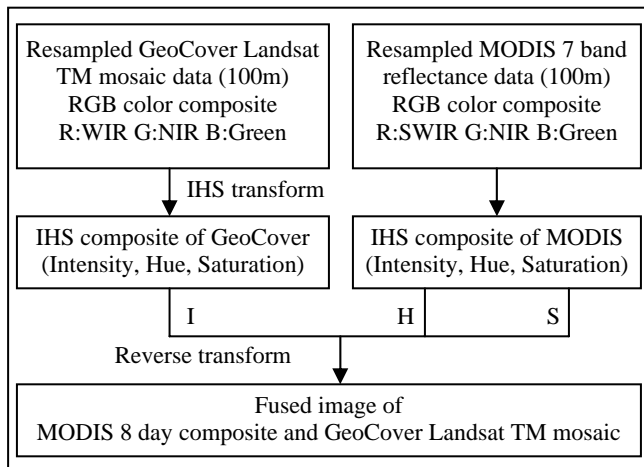


Figure 1. IHS transformation to fuse GeoCover and MODIS images

#### 3.2 Principal Component Analysis Method

The principal component analysis is statistical technique that transforms a multi variate inter-correlated data set into a new un-correlated data set (Zhang, 2002). The basic concept of PCA fusion is shown in Figure 2. The most important steps are; (1) perform principal component analysis to convert the 3 bands of GeoCover Landsat TM mosaic data into three principal components, (2) apply principal component analysis to convert 7 band MODIS 8 day composite reflectance data into seven principal components, (3) replace the first principal component of MODIS 8 days composite by the first principal component of GeoCover Landsat TM mosaic data, (4) perform reverse principal component analysis to convert the replaced component back to the original image space. Seven multi-spectral bands were reproduced after the reverse analysis.

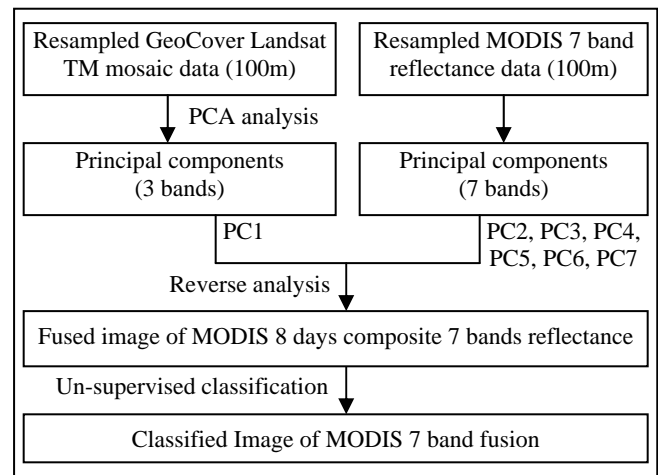


Figure 2. Image fusion by the PCA method

In this process the color characteristics of the original MODIS multi-spectral image are maintained, while we can observe the image at higher detail. To evaluate the usefulness of fusion products, the fused image was classified into number of classes.

### 4. FUSION RESULTS

In this section the results from the methodologies of IHS and PCA are discussed. The result of HIS fusion (image map) was evaluated visually. The classified image derived from PCA image fusion was compared with classified image of Landsat TM data.

#### 4.1 IHS Fusion

Figure 3 shows the RGB color combination of the reprojected MODIS 8 day composite reflectance image. The composite was created using the MODIS images acquired during the period of 1 to 8 January 2001. The image is in UTM projection system with the same size as GeoCover Landsat TM mosaic grid covering Krishna basin in South India. The spectral bands, which were used to create this color combination, are same as the GeoCover standard color combination (R: SWIR G: NIR B: Green). As the effect of

compositing multi-scenes, the western part of the image shows different in contrast. Some areas in the southeastern part of the composite image are covered by cloud.

The sharpened image derived from IHS method is given in Figure 4. By looking the image one can easily identify the sharpen effect. As the result of fusion, contrast different and the clouds on the MODIS composite image were eliminated. The improvement on the image can be clearly seen by comparing Figure 5, which is MODIS 8 day composite, and the IHS fused image that is shown in Figure 6.

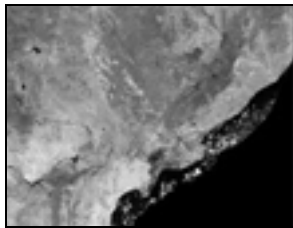


Figure 3. MODIS composite image of 1-8 Jan 2001 (R: SWIR G: NIR B: Green)

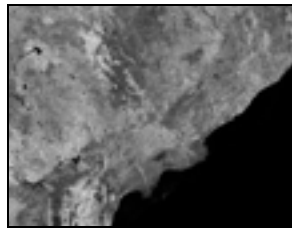


Figure 4. IHS fused image of 1-8 Jan 2001

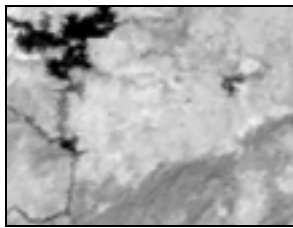


Figure 5. Subset of MODIS composite image of 1-8 Jan 2001

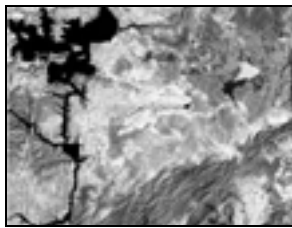


Figure 6. Subset of IHS fused image of 1-8 Jan 2001

The IHS method improves the spatial resolution and feature enhancement without significant distortion of color. To reduce the color distortion, the radiometric values of MODIS image and the GoeCover image should be matched and this was performed by histogram stretching. By using IHS technique, only three bands of MODIS composite can be utilized at a time.

#### 4.2 PCA Fusion

PCA fusion is a technique, which enhances the resolution of several bands of data. The PC1 of a higher resolution image replace the PC1 of a MODIS image, since PC1 contains the maximum variance, which maximize the effect of higher resolution image. Figure 7 shows the RGB color combination of a MODIS composite and Figure 8 shows fused image using PCA method (R: NIR G: Red B: Green). As with the IHS method, it improves spatial resolution and feature enhancement. As this method improves the spatial resolution of all seven bands of MODIS composite data, it is quite useful for classification purposes.

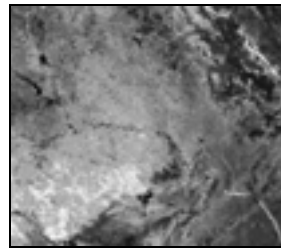


Figure 7. MODIS composite image of 17-24 Jan 2001 (R: NIR G: Red B: Green)



Figure 8. PCA fused image of 17-24 Jan 2001 (R: NIR G: Red B: Green)

#### 4.3 Classification

Figures 9 and 10 are the un-supervised classification results of PCA fusion of January 2001 and December 2001 respectively. On the classified images of Hyderabad area the irrigated agricultural areas are in dark gray. With the time series classified images the crop growth stages such as time of land preparation, planting and harvesting can be identified.

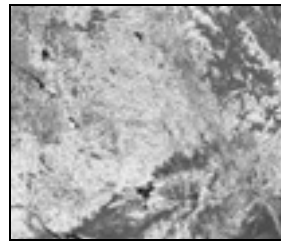


Figure 9. Classified image of PCA fusion (17-24 Jan 2001)

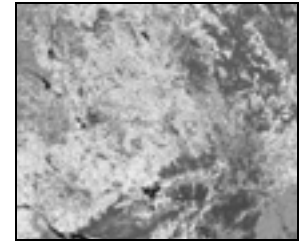


Figure 10. Classified image of PCA fusion (3-10 Dec 2001)

- Irrigated agriculture
- Natural vegetation
- Wet bare land
- Dry bare land
- Residential area
- Water

#### 4.4 Comparison

Working in the field of multi-sensor image fusion, the evaluation of the achieved results becomes relatively complex because of the different sources of data that are involved (Pohl and Van Gendren, 1998). It is even more difficult when multi-date composite data are used for data fusion. One of the possibilities is to validate findings from fused data by comparing with actual data sets or ground truth (Pohl and Van Gendren, 1998). In this study, for the purpose of validation, the classified image of MODIS-GeoCover fused image using the PCA method was compared with classified image of Landsat TM data acquired at the same time as MODIS. Figures 11, 12 and 13 respectively demonstrate classification result of MODIS composite image, MODIS-GeoCover fused image and Landsat TM image acquired during early January 2002. The comparison of images covering part of the Krishna delta clearly shows the spatial improvement in the classification accuracy in the fused image.

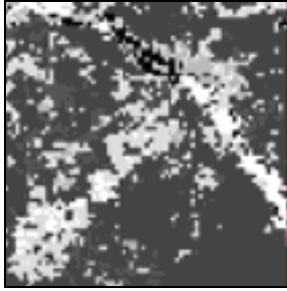


Figure 11: Classified MODIS composite image (1-8 Jan 2002)

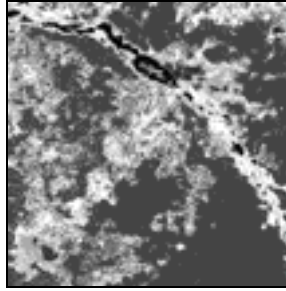


Figure 12: Classified PCA fused image (1-8 Jan 2002)

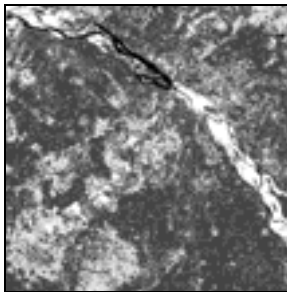


Figure 13: Classified Landsat TM image (3 Jan 2002)

- Irrigated agriculture
- Natural vegetation
- Wet bare land
- Dry bare land
- Residential area
- Water

For numerical comparison, the statistics of irrigated area derived from the MODIS composite image, fused image and Landsat image are given in Table A. This shows a slight improvement in the classification result of fused data (+15.2% of reference image) compared with the MODIS composite (+20.8%). Further detailed comparison will be made using better ground truth data, which is being collected for the unsupervised classes in the LandSat images in Krishna basin.

Table A. Statistics of irrigated area

Classified images	Irrigated Agriculture in 135800 ha area
Classified MODIS composite image	80375 ha
Classified PCA fused image	76678 ha
Classified Landsat TM image	66560 ha

## 5. CONCLUSION

Fusion of MODIS composite and GeoCover Landsat TM mosaic is an effective method in image processing which improves spatial detail whilst maintaining the spectral signature very close to the original. Therefore one can clearly identify the textural and structural features of land cover as well as the agricultural activities at the period of MODIS data acquisition. Moreover, it improves classification accuracy. The technique is seen as the first stage of a process in which free, coarse resolution MODIS composites can be analyzed

using a variety of multi-temporal techniques, ranging from characteristic signature extraction or through non-parametric approaches such as decision trees. This is the focus of continuing work to evaluate appropriate and affordable methods of global irrigated area classification. The technique is amenable to automation as the co-registration between MODIS composite data and the ortho-rectified GeoCover images is very good. The costs of image processing for time series data using automation will be investigated as part of the project activity.

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