A CHANGE VECTOR ANALYSIS TECHNIQUE FOR MONITORING OF VEGETATION REGENERATION AND DEFORESTATION:
A Case Study of Chiriapur and Shampur range: Haridwar Forest Division

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ABSTRACT

The Shampur and Chiriapur range of Haridwar forest division is an area where extensive forest areas are being destined to agriculture and cattle raising activities, contributing to the environmental and landscape change of this large region. In this context, this paper presents the method to detect the intensity of change and the dimension of change using Change Vector Analysis (CVA) method. On the other hand the commonly used method as post-classification change detection can only show the replaced and replacing classes but cannot determine the intensity and dimension of those changes. A pair of Landsat 7 images acquired almost in the same period of crop calendar of 1990 and 2000 is used to calculate the greenness index, brightness index, vegetation index and bare soil index (BI), which will be used as the change vector components. The technique produced images of change direction and magnitude between two dates based on the inputs of brightness and greenness, normalized difference vegetation index and bare soil index. Directing change indicated whether a landscape had experienced deforestation, reforestation, or remained persistent. Magnitude indicated to what degree the change occurred. The results of the study show the vegetation regeneration and deforestation occurred within the study area between 1990 and 2000. The method provided a clear-cut process for classifying and quantifying vegetation change.

Keywords: Vegetation Regeneration and Deforestation, Change Detection, Change Vector Analysis, Tasseled Cap Transformation, Normalized Difference Vegetation Index and Bare Soil Index.

1. Introduction

Vegetation analysis is one of the most fundamental applications of remotely sensed satellite imagery (Lawrence and Ripple, 1999). Monitoring change in vegetation between two time periods can assess the health and vigor of forest and plant species, assess vegetation growth and regrowth following a cataclysmic event, or quantify forest loss caused by deforestation and timber harvesting. Classifying these types of changes can be effectively performed using change vector analysis (CVA) (Lunetta et al., 2004). Change vector analysis (CVA) is a change detection technique that can determine the direction and magnitude of changes in multidimensional spectral space (Collins and Woodcock 1994).The method presented in this study includes various parts to analyze the change in different time period like, Normalized difference vegetation Index, Bare Soil Index as well as the derivatives of TC transformation. A cumulative Model been developed which is derived from integrated approach not only verify the change but also helps for prior monitoring and management of forest areas.

2. Study Area

The present study had been conducted in Chiriapur and part of Shampur forest range of haridwar forest division covering 195 Square Kilometer Surrounding area of Dehradun and Haridwar district, Uttarakhand. Study area is located at 29°43′N 78°20′E latitude and / 29° 56′N 78° 10′E longitude in Uttarakhand at an elevation of 640 meters and stands at the confluence of the Ganga rivers. The State Uttarakhand can be divided into three zones namely, the Himalayas, the Shiwaliks and the Terrai region. The study area covering part of shivaliks and terrain region. The study area has a temperate climate except in the plain areas where the climate is tropical with temperatures ranging from sub-zero to 43°C. The average annual rainfall is 1,550 mm. The vegetation type of the study area can be categorized mainly into five classes namely moist Shivalik sal forest, Dry plain sal forest, Northern dry deciduous forest and Khair sissoo forest.

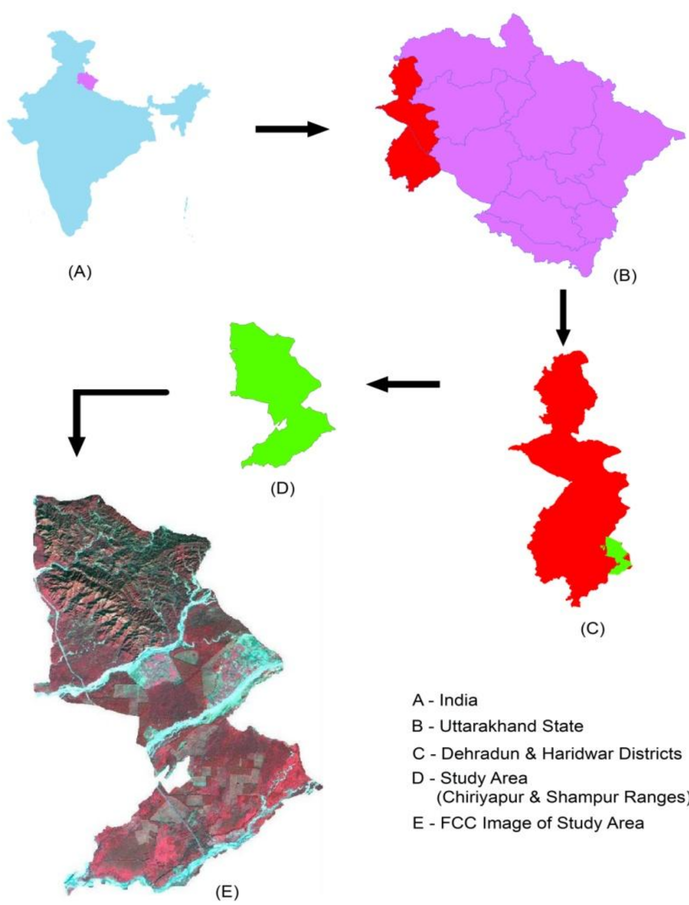


Figure 1- Study area map

3. Data and Methodology:

3.1. Pre-processing

Landsat TM and ETM+ images of the study area from two different years, 1990 and 2000, were analyzed in this study (Figure 2). Bands 1, 3, 4, 5, 7 from the Landsat TM 5 and ETM+7 sensors for respective dates were used for the analysis. Band 6 (10.4 – 12.5 μm) was not included in the analysis because the thermal infrared wavelengths are not required for performing Kauth-Thomas transformations (TC Component). The haze was removed from each band and digital number values were transformed into radiance values (Chander et al. 2007). This process standardizes each band so that the images can be compared without influence of atmospheric and environmental conditions or time of year.

3.2. Kauth-Thomas Transformation

While the CVA principle can be applied using original Landsat bands, it was decided to first transform the data from each date to the Brightness and Greenness variables of the Tasseled-Cap Transformation using data band 1,5,7 to reduce the redundant information of orbital images to be analyzed. These transformations produced new image features representing greenness and brightness based on new axes associated with biophysical analog properties of the scene (Lorena et al., 2002). Values of brightness highlight variations in soil reflectance throughout the study area while values of greenness represent vegetation cover. The combination of these new transformed bands offered biophysically interpretable inputs for change vector analysis (Kuzera et al. 2005).

3.3. Indices used

In order to get the comparable result, indices are used in closed association with Kauth - Thomas transformation in which in which Normalized Difference Vegetation Index (NDVI) and Bare Soil Index (BI) chosen as another change vector component. NDVI displays the relationship between the quantity of chlorophyll in leaves with red and near infrared wavelength, so that NDVI image is used to research vegetation as estimating biomass, plant productivity, fractional vegetation cover (Rouse 1974; Richardson 1977).

$$\mathbf{NDVI = (\rho_{Nir} - \rho_{Red}) / (\rho_{Nir} + \rho_{Red})}$$

= Where ρ_{Nir}, ρ_{Red} are the spectral reflectance measurements acquired in the near-infrared and red regions.

For more reliable estimation of the vegetation status, the new methods include a bare soil index (BI) which is formulated with medium infrared information. The underlying logic of this approach is based on the high reciprocity between bare soil status and vegetation status. By combining both vegetation and bare soil indices in the analysis, the status of forestlands on a continuum ranging from high vegetation conditions to exposed soil conditions.

BI= (ρ $_{Swir}$+ ρ $_{Red}$) - (ρ $_{Nir}$+ ρ $_{Blue}$) / (ρ $_{Swir}$+ ρ $_{Red}$) - (ρ $_{Nir}$+ ρ $_{Blue}$)

(Jamalabad 2004) Where ρ_{Nir} , ρ_{Red} , ρ_{Swir} ,ρ_{Blue} are the spectral reflectance measurements acquired in the near-infrared, red, short wave infrared, blue regions (band 4, 3, 5, 1 in Landsat ETM+ image).

NDVI and BI index are used in CVA method to stress the vegetative class and bare soil class that are the main classes to check the regeneration and deforestation.

3.4. Change Vector Analysis

In actual, the changed areas and the types of their changed are mapped out using the spectral change vector analysis. A spectral change vector describes land-cover change at the change magnitude (CM) and direction of change between the images pairs (1990/2000). *Change magnitude* is computed by determining the Euclidean distance between the two images across all image channels on a pixel by pixel basis. *Change direction* is specified by whether the change is positive or negative in each band on a pixel by pixel basis. The magnitude of vector represents the change intensity and the direction of vector represents the change dimension. In this study we will use the greenness and brightness part obtained from tasseled cap transformation as well as NDVI and BI index for calculation of change magnitude and direction. The equation to calculate CM is:

$$CM= \sqrt{(G_1-G_2)^2 + (B_2-B_1)^2}$$

Where:
CM = Change magnitude (Euclidean TC component distance)
G = DN values of Greenness
B = DN values of Brightness
1, 2 refer to respective TC component value for separate imagery dates

$$CM= \sqrt{(NDVI_2-NDVI_1)^2 + (BI_2-BI_1)^2}$$

$$tg\ \alpha = BI_2-BI_1 / NDVI_2-NDVI_1$$

CM: The magnitude of change vector (Euclidean distance)
α: The direction of change vector
$NDVI_1$, $NDVI_2$, BI_1, and BI2: NDVI and BI index at date 1 and date 2

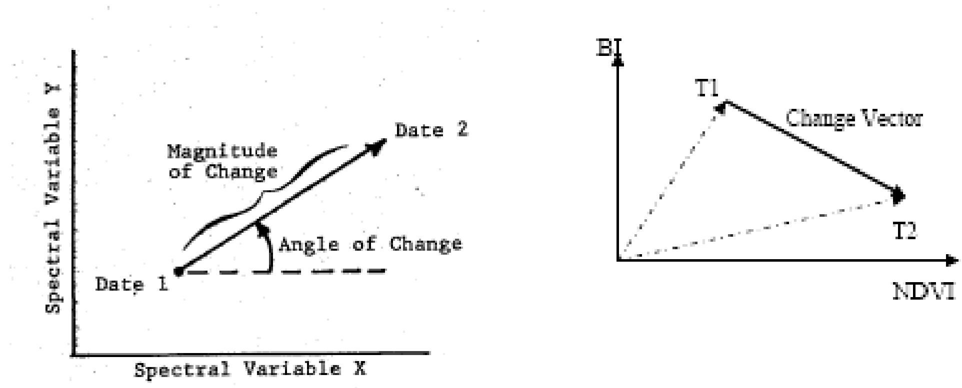


Figure 2- Illustration of a Spectral Change Vector in concept of Change Vector Analysis in two spectral dimensions and Locations of pixel in NDVI-BI space on T1 and T2 (T1, T2 are the acquisition date of images).

The change directions in two-band spectral space are classified as follows:

Greenness \ Brightness	-	+
-	**1**	**2**
+	**3**	**4**

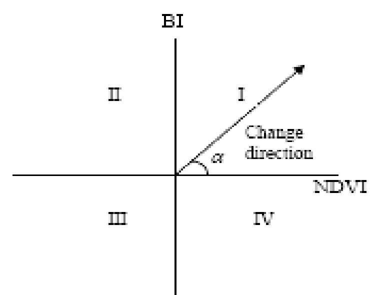


Figure 3- Illustration of a Spectral Change Direction in different data-takes.

The angle of the vectors, which shows the change that occurred, varies according to the number of components used (Table 1). In other words, each vector is a function of the combination of positive or negative changes through channels or spectral bands, which allows to distinguishing 2n types of changes. Since only components Greenness and Brightness were used in this study, only four classes of change were possible. But we would examine only two changes and remaining two put into persistent one. The overall methodology of this study is calculated using Spatial Modeler tool in Erdas Imagine software.

4. Results and Discussion

4.1. Change intensity image and change dimension image using TC transformation

The histogram of change intensity image is analyzed to detect change or no change threshold. The change dimensions are built following the 4 directions.

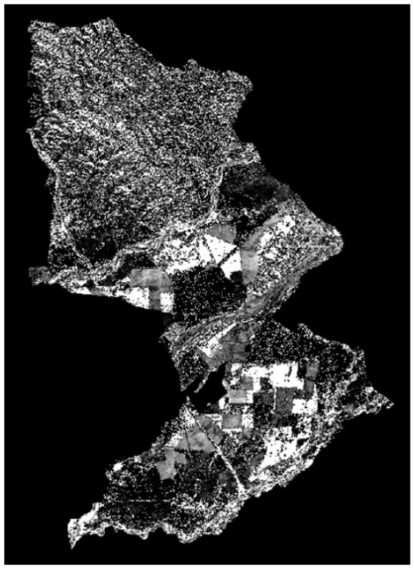


Figure 4a- Image of change intensity (2000-2002)
(*The more brightness the high level change*)

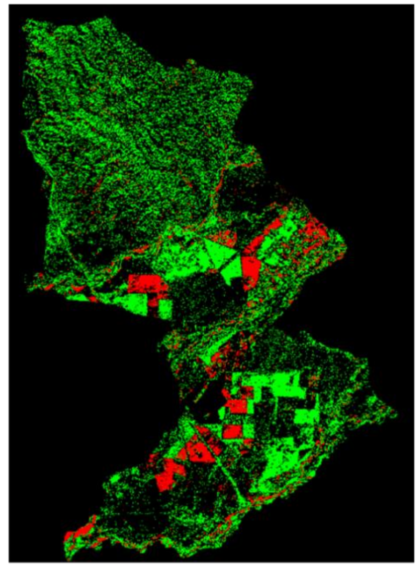


Figure 4b- The image of change dimension

Classes of Change	Brightness	Greenness	Result
	-	+	Regeneration
	+	-	Deforestation

Table 1 – Possible change classes from both input components and related types of changes.

Class 1, which indicates increase in Greenness and decrease in Brightness, represents a direction of the vector that is mainly related to the growth of vegetation biomass, while Class 2, indicating decrease in Greenness and increase in Brightness, is strongly related to great losses of vegetation biomass as a result of the clear-cut of forest. Class 3 and 4 merged into one class, represents the persistent.

A threshold of final magnitude was defined for each one of the change classes through an interactive adjustment (Table 2). The main function of the threshold was to set out the spectral information that is related to each of the Classes of Change.

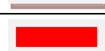
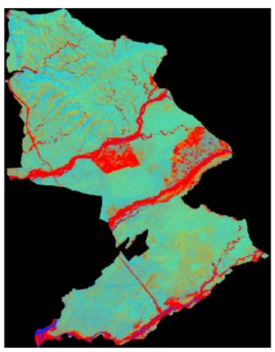
Classes of Change	Thresholds 1990/2000
	8
	15

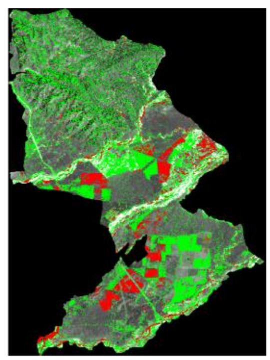
Table 2 - Magnitude thresholds of change for each class during data-take analyzed.

Figure 5 – Examples of thematic changes: = increase vegetation growth; = decrease in vegetation amount

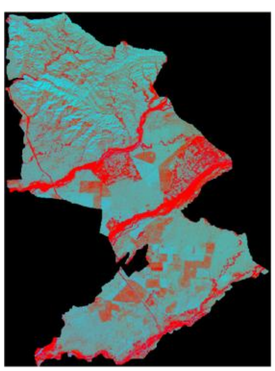
Using the change threshold mask, we determined the result related to 4 possible Classes of Change. It was further grouped as Class 1, which represents regeneration and biomass growth, would be represented by green; Class 2, that represents deforestation, by Magenta; and other Class 3 and 4 merged into one class, represents the persistent area.



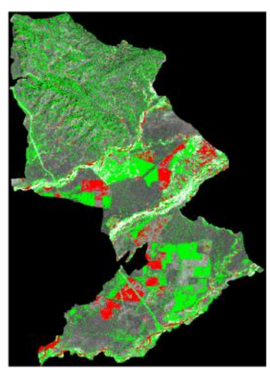
TC Image (1990)



Change Vector image 1990-2000 (background scene: Brightness image- 1990)



TC Image(2000)



Change Vector image 1990-2000 (background scene: Brightness image- 2000)

Figure 6 - Change Vector image (1990-2000) in comparision to their TC image (background scene:Corresponding Brightness image).

4.2. Change intensity image and change dimension image using NDVI and Bare Soil Index Model

The Change magnitude and change direction is also calculated using two NDVI and bare soil indices. The indices and corresponding change intensity and change direction were calculated using spatial modeler tool in Erdas imagine. Similar to the analysis of TC transformation change intensity image the histogram of change intensity image derived from both indices is analyzed to detect change or no change threshold. The change dimensions are built following the 4 directions on trigonometric circle as in figure 2.

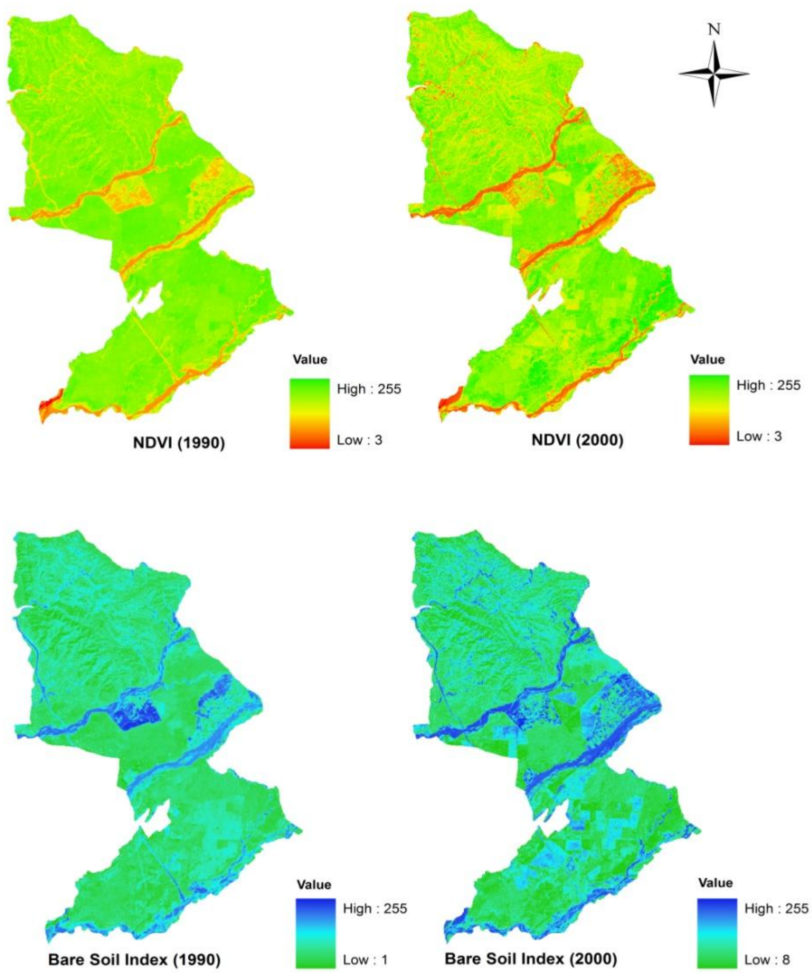


Figure 7 – NDVI and BI images of corresponding year (1990& 2000)

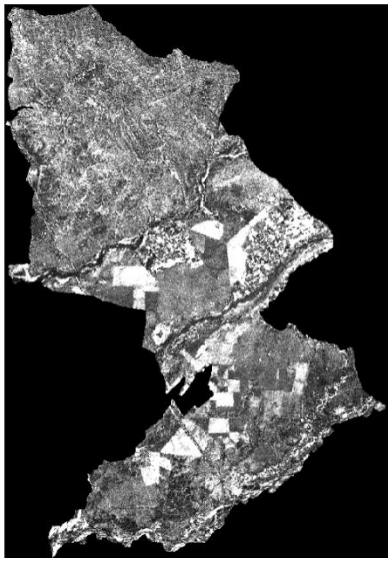


Figure 8a: Image of change intensity (2000-2002)
(*The more brightness the high level change*)

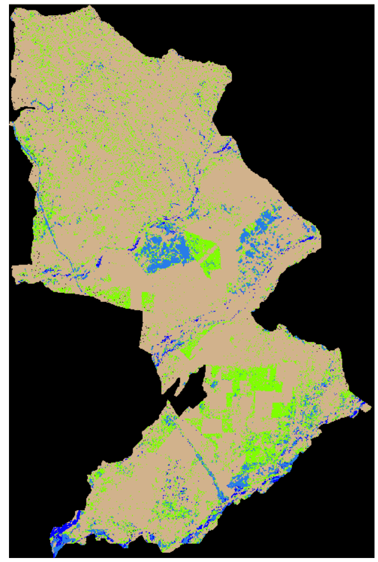


Figure 8b: The image of change dimension

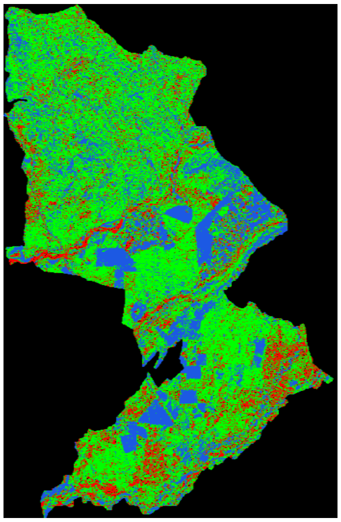
Change Dimension	BI Index	NDVI Index	Result
	-	-	Water or high moisture land
	+	-	Bare soil expansion
	-	+	Chlorophyll Increase
	+	+	Moisture reduction

Table 3 – Possible change classes from both input components and related types of changes.

The above table clearly represents all possible change direction in 4 dimensions. The decrease in both of the NDVI and BI index in the dimension I show the water or high moisture land. Comparing the change intensity image with the change dimension image, the location of the dimension II area similar to the location of high- level change area and were easily depicted. In area of the dimension III, the quantity of chlorophyll of tree cover is more. That is the reason of the NDVI increase and the BI decrease. The dimension IV shows the increase in both of the NDVI and BI index. The cause of this phenomenon is the moisture fall between dates.

4.2.1 Threshold detection for change / no-change areas

In CVA technology selection of a threshold value is required above which change can be considered significant land-cover change, in comparison to changes that might result from the fluctuations of other environmental characteristics. A good approach is to start with the highest CM values as they likely really are change and then begin changing the increasingly lower values one by one until you get to a threshold value that is questionable as to whether it is truly land-cover change or just a minor variation between the two images. The change detection threshold, therefore, was determined using the interactive expert knowledge of the study area, similarly to many remote sensing techniques such as an unsupervised classification where expert knowledge of land cover classes within the study area is required to relate spectral clusters to land cover types (Jano et al. 1998). In this study, we divide the Change intensity image into 3 classes as in Figure 4.



Classes of Change	Name	Description
I (red)	No Change	Spectral no change
II (green)	Low Change	Spectral change
III (blue)	High Change	Land Cover Change

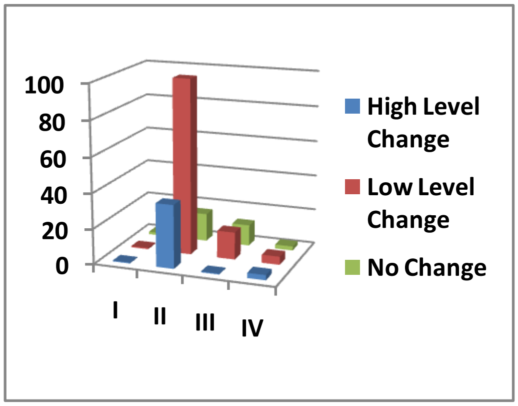
Table 4 – The results of the change intensity analysis between 1990 And 2000 classified.

Figure 9: The change intensity image after threshold divided.

Class I is the areas, which changes spectral at little level, so it can be ignored and consider as no change in the study period. Class II is spectral change areas but it doesn't show classes replacement. Class III stands for the change of quality inside each class of land cover. The replacement a class by another class is showed in Class III that is changes at high level.

Change intensity image and change dimension image are used to get the quality of change of each level through the relation between change intensity and change dimension.

	I	II	III	IV
High Level Change	45.56	3584.45	47.76	289.16
Low Level Change	77	9927.15	1551.31	463.06
No Change	138.32	1599.15	1200.5	234



The Change Vector image of the two periods studied allowed verifying the afforested or the regrowth area was near 30 Km2 in the 1990-2000 periods which is concluded by both the methods. Figure 5 shows the distribution of change and no change areas in all four possible directions. The no change area is distributed equally among 4 dimensions. On the change intensity image, the no change areas are ponds, clean rivers. The change of reflectance spectral value is usually disturbances in remote sensing technology.

5. Conclusion

In this study we intend to test the components of different types for the CVA procedures which were derived from the Tasseled Cap analysis (Greenness and Brightness components) and other 2 parts (NDVI and BI index). The cross-tabulation of tasseled Cap analysis (Greenness and Brightness components) produced an easily interpretable map of regeneration and deforestation without the need to designate training sites. The technique used in this study eliminates the difficult task of manually categorizing patches of land that are either regenerated or deforested, and at their specific magnitudes. NDVI and BI index is also an effective tool in assessing land cover/ land use change. The study shows that, CVA method using NDVI and BI index is fully suitable for pure agricultural area, the forested area having different types of vegetation vigourness and high reciprocity between bare soil status and vegetation status. By combining both vegetation and bare soil indices in the analysis, one may assess the status of forestlands on a continuum ranging from high vegetation conditions to exposed soil conditions. In this study, the application of change vector analysis using different component to Landsat data appeared to be a consistent and low-cost technique to obtain information on vegetation cover, bare soil index and identify risk areas for management of deforestation and regeneration.

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