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Agricultural Landuse Change Detection using Change Vector Analysis in Lower Velar Watershed

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***Abstract*—Agricultural land-use change study is a vital field in global environmental change research. The rapid urbanization and industrialization has caused the dramatic changes in agricultural land-use. The study on agricultural land-use change detection plays a significant role in environmental change. In this study, Change Vector Analysis method was used to detect the agricultural land-use changes between 2000 and 2015 using Landsat ETM+ and OLI/TIRS images. The difference images were generated by image differencing method. Threshold value for detecting the agricultural land-use changes was generated using Z-score method and also based on experts knowledge. The direction of change indicated the trend of agricultural land-use change and the magnitude indicated the changes in a quantitative manner. Finally the results were validated using crop acreage data from 2000 to 2015**

Keywords: Change Vector Analysis, Landsat ETM+, Landsat OLI/TIRS, Difference image, Z-score.

I. INTRODUCTION

Land is classified into four types mainly residential, agricultural, commercial and industrial. The vegetation in an area depends mainly on the agricultural land cover. In order to measure and evaluate the economic development of any area, it is essential to detect changes in agriculture over the years. It is also important in order to take any precautions to preserve the environment and agriculture of the area. The changes in agriculture is due to many man made or natural reasons. The different natural factors that affect the vegetation of a region are flood, drought, cyclones etc. On the other hand, various human factors that affect the vegetation cover are migration of people, urbanization of rural areas, industrial development, mining etc,

Inventory and monitoring of agricultural land-use changes are indispensable aspects for further understanding of change mechanism and modeling the impact of change on the environment and associated ecosystems at different scales [1]. It is important to take care of such effects to preserve the vegetation cover as well as the agricultural stability of the region.

Change detection in watersheds helps to enhance the capacity of local governments to implement the sound environmental management [20]. This involved development of spatial and temporal database and geospatial based analysis techniques. Efficiency of the techniques depends on several factors such as classification schemes, spatio-spectral resolution of remote sensing data, ground reference data and also an effective implementation of the result.

Remotely sensed images provide a means to study the process and the change patterns of environments and ecosystems over a range of spatial and temporal scales [2][3][4] due to its capability of detecting changes in an effective, consistent, and accurate. Digital image processing of satellite data provides tool for analyzing the image through different algorithms and mathematical indices.

Change Vector Analysis (CVA) is a technique where multiple image bands can be analyzed simultaneously. CVA does not only function as a change detection method, but also helps in analyzing and classifying the change. In CVA, pixel values are vectors of spectral bands [4].

Change vectors (CV) are calculated by subtracting vectors pixel-wise as in image differencing. The magnitude and direction of the change vectors are used for change analysis. The change vector magnitude can indicate the degree of change. Thus, it can be used for change and no change classification [3][6].

II. STUDY AREA

The study area is a part of Ponnaiyar and other sub basins and bounded with Latitude - 11°25’32”N to 11°35’54”N, Longitude -79°40’11”E to 79°50’20”E and comprises of 9 micro-watersheds. The total area of the watershed is 1015 km^2.

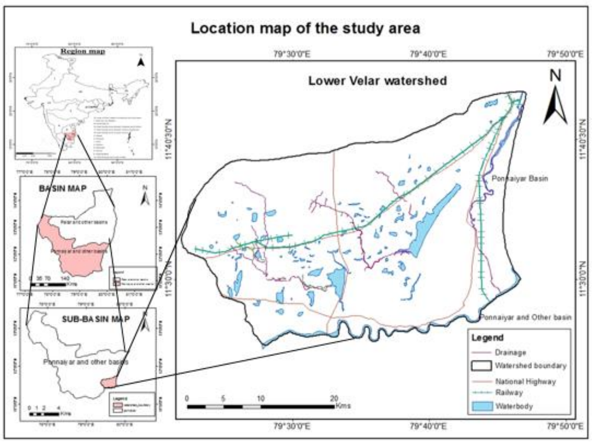

Fig. 1. Location map of study area

The climate of this region is characterized by a long and severe summer, moderate monsoon and mild winter. Summer months are from March to May, followed by the south-west monsoon (June to August). The high precipitation monsoon months are September to December, where the area is influenced by the Northeast monsoon followed by winter months.

The average rainfall of SW monsoon is 410 mm, normally starts in 2nd week of June and cessates in 4th week of September and average rainfall of 651mm, and it normally starts in 2nd week of October and cessates in 4th week of December. The annual rainfall of the study area is 1061mm.

The study area is predominantly covered by sandy clay loam and clay loam which is highly suitable for agriculture crops like rice, sugarcane, groundnut, pulses etc. The temperature is warm during the summer months with a maximum temperature of 41^0 C in May. The lowest temperatures range between 18^0 and 21^0 C in winter months. The study area includes three opencast lignite mines (Mines I, IA and II), associated with three thermal power plants that are operated by Neyveli Lignite Corporation Ltd. (NLC) & STCMS (STCMS – Lignite firing power plant) at Uttangal, Neyveli-5.

The study area is underlined by geological formations, ranging in age from the Tertiary to recent alluvium sediments. The major soil types found in this basin are inceptisol, entisol, alfisol and vertisol.

III. METHODOLOGY

A. *Preprocessing*

In any change detection study, the importance of accurate registration between images being compared cannot be overstated and notes that "accurate spatial registration of at least two images is essential for digital change detection" [14]. Image registration is the "translation and rotation alignment process by which two images of like geometries can be put together in same position. The same set of objects are positioned and coincided with respect to one another so that corresponding elements of the same ground area appear in the same place on the registered images" [5]. The Landsat images are used in this research have been ortho-rectified to remove distortion due to topographic variation. It is also important that the image pair be well registered to each other and to the open series map used for ground truthing and accuracy assessment. The importance of radiometric correction among multiple images of the same area as a pre-processing step in change detection and other applications has been done repeatedly. Radiometric correction can be defined as a process intended to "remove radiometric differences between multi-temporal images that are due to non-surface factors" in pursuit of a common radiometric response, required for quantitative analysis [12].

In fact, the goal is that "all rectified images should appear as if they were acquired with the same sensor, while observing through the atmospheric and illumination conditions of the reference image" [13][21]. Hence changes in pixel values will reflect actual changes on the surface. Through a number of normalization techniques the user can reduce the effects of differences in scene illumination, atmospheric conditions, viewing geometry, and instrument response characteristics [15][20]. The result is a reduction of error and a more accurate, reliable image analysis product, an "improvement in visual image quality and statistical robustness". Accurate normalization is essential for image processing procedures that use multi-date imagery, such as change detection. Initially, images were geometrically corrected and ENVI was used to rectify the images radiometrically. FLAASH (Fast Line of sight Atmospheric Analysis of Spectral Hypercubes) is an effective tool that correct wavelengths in the visible through near-infrared and Short-wave infrared region. It incorporates the MODTRAN4 radiation transfer code [15][16]. First all the bands were converted from reflectance to radiance. Layerstack the radiometrically calibrated bands and perform the FLAASH analysis using ENVI.

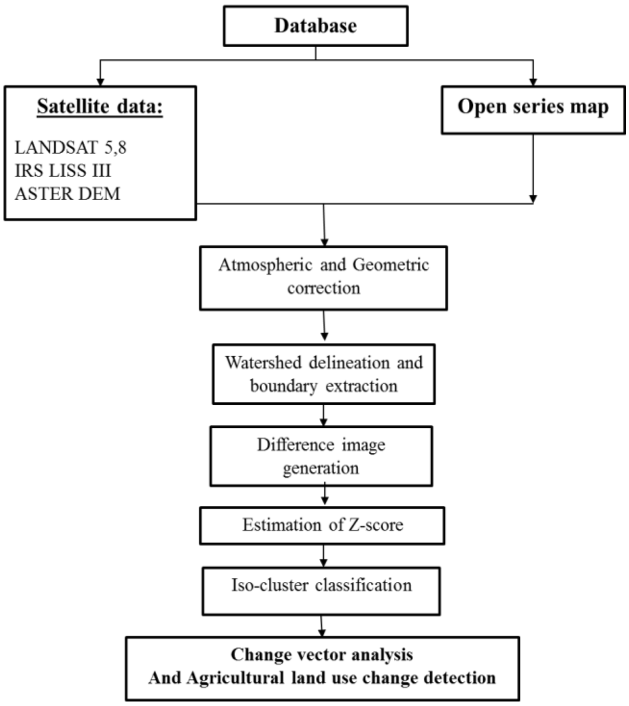

Fig. 2. Methodology flowchart

B. *Change Vector Analysis*

A change vector can be represented as a method of detecting radiometric changes between multispectral and also multi-date satellite data in any number of spectral bands. It is described by an angle of change (vector direction) and a magnitude of change from date 1 satellite image to date 2 satellite image of the same geographical area and same spectral bands [14]. CVA method extracts information about both the magnitude and the direction of changes in the data, so that the changes are characterized by vectors having magnitudes and directions in two dimensional spectral change space [3]. If a pixel's reflectance values in two images on date t_1, t_2, are given by $I_1 = (I_{11}, I_{12}\ldots I_{1N})$ and $I2 = (I_{21}, I_{22}\ldots I_{2N})$. The change vector can be expressed using the equation 1,

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$$I = I_1 - I_2 \quad (1)$$

Where, the magnitude can be estimated using the equation 2 of the Euclidean distance in an N-dimensional (spectral space equal to number of bands) space [3][4].

$$\| \Delta I \| = \sqrt{} (I_{21}-I_{11})^2 + (I_{22}-I_{12})^2 + \ldots\ldots (I_{2n}-I_{1n})^2 \quad (2)$$

A change in the pixel depends on whether change magnitude exceeds a specific threshold. Once change pixel is identified, the direction of ΔI can be analyzed further to determine the type of change [4]. The type of change is identified using the angle of the change vector, cos θ, in two dimension spectral space using the equation 3,

$$\text{Cos}\theta = \Delta I / \|\Delta I\| \quad (3)$$

C. Image Differencing

Image differencing simply involves the subtraction of the digital pixel values of an image of the particular date with the corresponding pixel values from different date. This method is favored by many for its accuracy, simplicity of computation, and ease of interpretation. The resulting difference in pixel values is an indication of positive or negative change, or lack of change in land cover type or other variable studied. Statistical thresholds to indicate presence or absence of change in a given pixel, band or component are an important element in producing an accurate and meaningful change detection product. Image differencing can be performed using raw pixel values, or using new pixel values resulting from any number of image algebra transformations.

D. Determining of the Threshold Value-Z Score

In change detection using remote sensing data, thresholds are used to define changes and no change pixels from the continuous images produced by image differencing.

Threshold selection is generally the most subjective, and often less accurate. To determine the appropriate change threshold that is sensitive to real changes in land cover and vegetation while reducing the appearance of "false changes".

In this study, thresholds were based on z-scores for each change image variable, so that levels of change could be standardized and compared between image transformation methods irrespective of the range of values in the change images themselves. This method is based on the fact that "pixels of no brightness value change are distributed around the mean and pixels of change are found in the tails of the distribution." [14][15]. A z-score change image was generated using the equation 4,

$$z = (x - \text{mean})/\text{sd}, \quad (4)$$

where, x is a pixel value, mean is the mean pixel value for all pixels in the image, and sd is the standard deviation.

IV. RESULTS AND DISCUSSION

A. Difference Image

The Landsat images of February 2000 and March 2015 were taken and image differencing was performed between 2000 and 2015 images.The images should contain equal number of bands, if not differencing will not be properly done. The layer stacking was done using True Color Composite of Landsat TM images and band Landsat 8 OLI/TIRS images respectively. Image differencing were done using Image Differencing method in ERDAS IMAGINE software.

Each pixel in Landsat image of 2000 was subtracted by corresponding pixel in Landsat image of 2015 and the output image provides the results with five different classes includes Decreased, Some Decrease, Unchanged, Some Increase, and Increased, based on percentage of change.

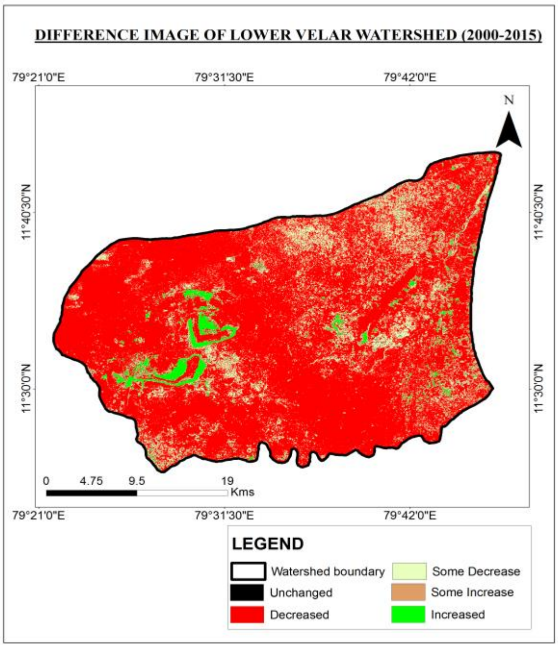

Fig. 3. Difference image of Lower Velar watershed

The classes Decreased and Increased in Differenced image indicates more changes, Some Decrease and Some increase indicates less changes and Unchanged class indicates no change respectively.

B. Determination of Threshold value (Z-score method)

Pixel values from the Difference image wa standardized using z-scores method. The statistics and formula was used to generate a z-score image from change image. Mean and Standard deviation of the image was calculated using Statistics option using ERDAS 9.2 and the normalization of Mean and Standard deviation values of Difference image was done using Euclidean distance method.

TABLE 1. CALCULATION OF THRESHOLD VALUE (Z-SCORE METHOD)

Method	Mean pixel value	Standard deviation	Equation
Z-score	0.095	0.168	(x-0.095)/0.168

The threshold values determined using z-score method were plus or minus 1.0-3.0. Based on interpretation from different threshold values and experts knowledge, it was decided that +- 1.25 z-value threshold is the more accurate and it clearly defining areas of change and no change pixels of agricultural land use in the images.

C. Change Map

The conditional expression was applied on the difference images with threshold values using ERDAS Imagine modeler, images were recoded into thematic change images containing two classes: Decreased (1), Unchanged (2).

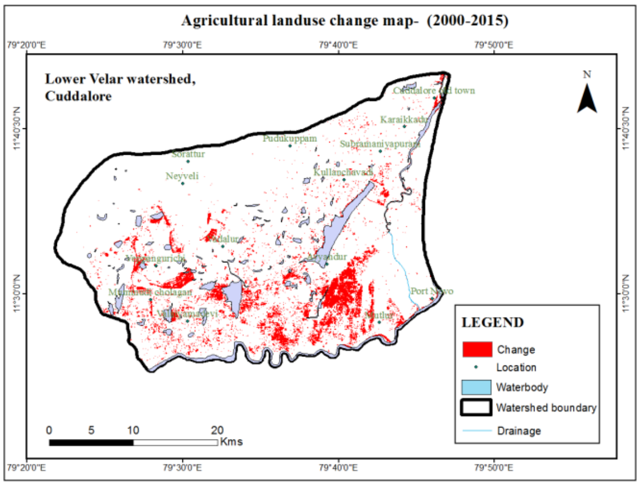

Fig. 4 Change map (2000 – 2015)

The changes observed in result is due to variation in onset of monsoon, intensity and distribution of the rainfall. These climatic factors affecting soil properties, irrigation and other requirements for crop growth significantly.

TABLE. 2. AGRICULTURAL LAND USE CHANGES DURING 2000-2015

Period	Agricultural land use change(in km^2)
2000 - 2015	241 km^2

To grow the crops in these conditions requires more capital investment and this induces the farmers to leave the land as temporary fallow or in worse conditions they may lead to sell their agricultural lands to real estate people.

The changes were more near neyveli, portnovo, banks of perumal lake and coastal part. Changes near neyveli was due to development of mines and because of the development ground water moves from surrounding area to low lying area and this leads to lack of groundwater for agriculture use. Changes around the banks of perumal lake due to the lack of monsoon precipitation in South-West monsoon and this induces the changes and other areas were affected due to sea water intrusion, lack of precipitation and variation in onset and cessation of rainfall.

D. Agricultural Land use change - A Statistical Validation study

Agricultural land use area change was gradually decreasing from 2000 – 2015 (as shown in fig. 5) Due to various factors such as climatic conditions, groundwater level and quality, urbanization and industrialization, lack of manpower and capital, extreme conditions such as flood, cyclone etc.,.

Major factors influencing agricultural land use change in the Lower Velar watershed were discussed as follows.

Climatic conditions such as rainfall and temperature playing an important in agriculture. In Lower Velar watershed, large amount of amount of rainfall occurred in a short span of time (between October and November) and hence the distribution of rainfall is less. Because of the less distribution of rainfall, most of the water started as a runoff and finally it reaches the sea. The temperature of the study area increases because of the industries in SIPCOT produces more amount of CO_2 and this CO_2 leads to increase in temperature and crop such as rice, sugarcane, groundnut could not able to tolerate the temperature and finally it reduces the yield (as shown in fig. 6).

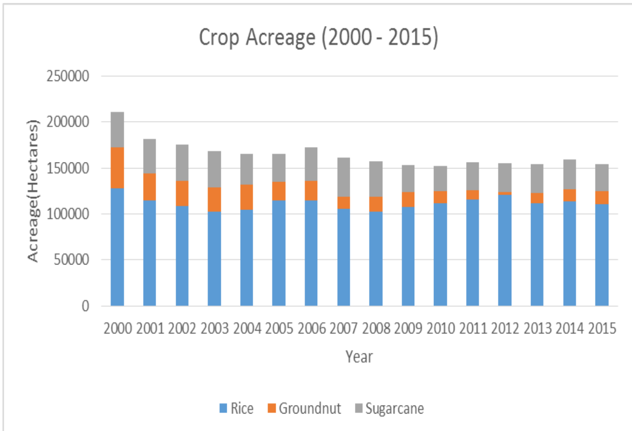

Fig. 5. Crop acreage statistics (2000 - 2015)

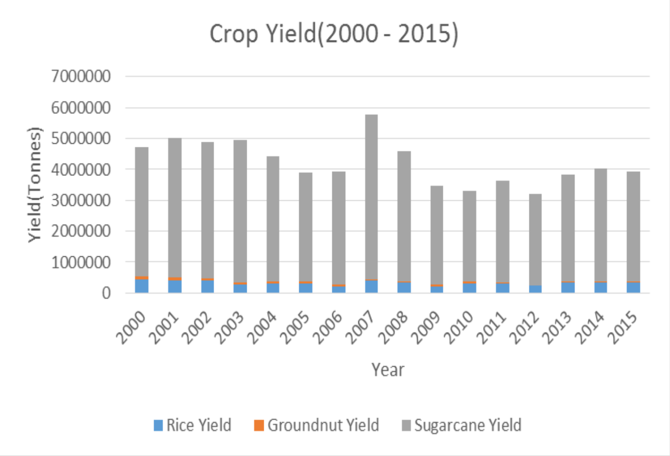

Fig. 6. Crop yield Statistics (2000 - 2015)

The groundwater level is only one of the important factor which decrease the agriculture. The changes in groundwater level is significantly observed near Neyveli Lignite Corporation and level of ground water in 1992 was 2m from the surface and it is nearly 50m from the surface in 2015(source: Central Ground Water Department). And groundwater is polluted by Textile industries located inside SIPCOT by releasing their sludges and other liquid waste which contains magnesium, calcium, chlorides, chromium etc., into the ground and dumping their solid waste in the nearby area which contaminates both ground and surface water significantly (source: TNPCB).

Extreme conditions such as floods and cyclone in the area and this condition occur frequently in Lower Velar watershed, such as Tsunami in 2004, floods in 2003, 2006 and 2015, cyclones such as Thane and some minor cyclones cause severe damage to the agricultural land and this affects the farmers greatly.

Even though the rainfall and other climatic parameters were abnormal, agriculture is still their main business and most of the people in this area depend on agriculture and its allied fields only.

V. CONCLUSION

The CVA technique's effectiveness in detecting vegetation cover change was tested. This technique is fully automated and the approach employed in this study made use of 4 bands of Landsat image time series. The conversion of the bands to Difference images reduced the dimensionality of the bands and at the same time highlighted vegetative properties of the landscape.

The technique avoids the use of training sites and land cover categorization. Nevertheless, a priori information is needed if the CVA change image is to be interpreted correctly. Also, the technique fails to provide concise from–to. Instead, it offers qualitative information concerning the direction in which the vegetation is evolving and the intensity of the change. As a whole, CVA is one of the best methods to detect agricultural land use change.

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