# Analysis of various time series change detection techniques: An empirical review

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***Abstract*— *Time series change detection techniques have various uses, ranging from data classification, prediction, clustering and application based inference. These data mining techniques on time series change detection are usually application specific but the concepts are equally applicable to any other application area of research. In this paper, we have performed an empirical analysis of some standard algorithms on time series analysis, and evaluated their performance. This analysis has enabled us to identify some algorithmic traits which are specific to a given area of research, and thus would help researchers in selecting base algorithms for their own research purposes. Although, the techniques reviewed in this paper are targeted towards forest cover datasets, but are applicable to any other dataset as per application requirements.***

***Keywords:*** ***Time series, mining, classification, clustering, prediction, forest cover change***

## 1. INTRODUCTION

Recording of variation in data values w.r.t. time is the most common way to read and process real time data. In such a scenario, the recorded values show the variance of the data samples of one particular area in accordance to its temporal properties, and thus can be used to predict and analyse the inherent properties of the area under test. A strong classification engine is needed in order to make proper inferences from the recorded temporal data. As mentioned in [1], various classifiers and land areas are tested in order to evaluate the forest cover time series data, and probability is evaluated in order to check for the effect of deforestation in the areas under test. Using the time series data, the researchers in [1] have evaluated Normalized Difference Vegetation Index or NDVI, Vegetation cover proportion or VCP, Soil Adjusted Vegetation Index or SAVI and Normalize Difference Water Index or NDWI. Their research claims to have more than 95% accuracy of classification using machine learning based classifiers, for different types of land cover forest classes. They have used the classes of Forest, Woodland forest, other classes, land and water.

Some researchers have claimed to be using bi-temporal detection of change [2] by using geometric processing, detection of clouds and change vector analysis or CVA. The CVA method relies on multi dimension feature reduction along with expectation maximization (EM) in order to detect the changes in vegetation of a specific area. In the same research they have also predicted seasonal trend decomposition in order to predict the seasonal changes in the data. Techniques like these and more are analyzed further in the next section of this paper. The paper also suggests some ways in which some of the techniques can be improved in order to further optimize the accuracy of classification and prediction in existing standard systems.

## 2. LITERATURE REVIEW

In this section, we will be reviewing multiple algorithms for forest cover change detection as an application for time series change detection. Most of the reviewed techniques either use Landsat data, LiDAR data or similar standard time series datasets for prediction, clustering or classification purposes. As shown in [2], the researchers have used Landsat data for more than 18 years in order to analysis the bi-temporal changed in the datasets. Their analysis is based on image processing, wherein the researchers have applied the CVA algorithm and obtained about 93.4% accuracy (in some cases) of classification and change detection for the datasets, while the overall accuracy is limited to under 70%, this method serves as a base line for any image processing application which might need to perform time series detection. This method can further be improved by using machine learning or fuzzy logic rule engines, but the final evaluation will only be clear after implementation of the suggested modifications.

Another research work as mentioned in [3] claims to have analyzed time series information provided by the MODIS dataset, and uses it in order to evaluate forest fires, deforestation and natural disasters. They are using linear classifiers in order to detect these phenomena and have compared their results with Google Earth imagery. Though there is little clarity given about the accuracy of their research, but it seems to be more than 60% accurate when their results are manually observed by the tables and graphs provided in the paper.

Analysing annual data is also of significant importance when it comes to critical areas of forestation. The MODIS dataset is used in [4], and the accuracy of disturbance in forest cover around Washington State in USA is evaluated and compared with the machine observations given by the Landsat dataset. These researchers have claimed to have achieved around 59% current year accuracy, and about 84% subsequent year prediction accuracy. The researchers have been using Vegetation Continuous Fields based Change Analysis (VCA) methods in order to achieve these results. They have also compared their results with PRODES project which is based on Deforestation Monitoring in the Brazilian Amazon by the Brazilian National Institute for Space Research.

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While Landsat is one of the standard sets for imagery analysis in time series change detection for forest covers, another dataset namely corona is used by researchers in [4] in order to map the change in forest cover in eastern US and central Brazil. They have analyzed data from mid-1960s to 2000s for achieving the results. As per their claim after applying the second order polynomial transformation on corona images resulted good geometric accuracy as achieved by using the landsat-7 imagery. As per their claim, they are able to evaluate the forest cover change with more than 95% accuracy in persistent forests, more than 93% accuracy in persistent non-forest areas, more than 74% accuracy for forest loss and 50% to 94% accuracy in forest gain. The researchers have used Co-occurrence textures and various other combinations of texture features in order to obtain their results.

Some research works also go into classification and mapping of forest types based on leaf extraction algorithms. Such a research is done in [5], where the researchers have used the Light Detection and Ranging or LiDAR data. In that work, they have used various software tools for mapping and forest type classification. These tools include but are not limited to Matlab, Canopy Height Model (CHM), Canopy Cover Model (CCM), and Digital Terrain Model (DTM) and the neural network toolbox. They have also used a testing algorithm named T-test in order to test the overall system accuracy, which is found in the range of 90% to 93%, and an overall precision rate between 90.40% and 99.14%. This is one of the unique approaches which we came across, due the fact that this approach uses leaf segmentation techniques in order to evaluate the forest cover type, and is able to achieve a very good accuracy due to the use of neural networks in the system. While software tools play a major role in the overall evaluation of the system, but the concept behind the evaluation is unique in itself.

Simple methods like distance metric based detection of change in forest cover is proposed in [6], where the authors have used NASA's Moderate ResolutionImaging Spectroradiometer or MODIS data along with Nadir BRDF-adjusted Reflectance or NBAR, in order to obtain around 77% accuracy. The paper also uses a combined spatial and temporal gap-filling pre-processing step combined with Mahalanobis & Euclidean distance metrics. These metrics along with distance thresholding based on 90% and 95% quantiles of empirical distributions have proven to effective enough for getting better analysis accuracy than the compared single distance metric based method.

While the above mentioned methods use close to forest image processing, a controlled experiment using the ALOS PALSAR dataset has been performed in [7] for clear-cut quantification in satellite images. The given dataset assisted the authors by providing forest change imagery across summer, fall and winter seasons. This research indicates a backscattering coefficient of around 2.1 dB, which detects more than 60% of the detected cuts accurately. This method can also serve as a base for satellite data based forest cover change detection, but can be further improved by gathering more data and training a deep neural network in order to evaluate the system with different angles of images from satellites for the same area under consideration. This work is not yet carried out, but due to the previous record of deep neural networks, it will surely provide a better accuracy when compared to the traditional methods as used by the researchers in their work.

Usually to perform time series data analysis researchers use accuracy based measures as seen from the above methods, but the authors in [8] have used an error model based method for mapping forest cover and change in forest cover using L-Band SAR or synthetic aperture radar images. This dataset was taken from the semi boreal forest in southern Sweden. The error model is based on a backscatter model that uses scattering data from forest floor through gaps in the canopy, attenuated by the canopy and scattering from the canopy. The error model uses less dense areas and highly dense areas for performing this experiment. The accuracy of this novel model ranges from 70% to 90% based on the observations which are evaluated by the proposed algorithm by the authors. This model has it's own unique properties, one of which is the concept of reverse engineering in order to propose an error model for performing the time series change detection in forest covers. Very few papers have used models like these in order to evaluate time series change, and thus it would be too early to suggest any novelty in the given error model.

Another research, which evaluated multiple algorithms for mapping forest degradation and disturbance, is suggested in [9]. This research concludes that there are already multiple algorithms for time series processing in forest datasets, but still some research can be done for high resolution temporal series taken using multiple sensors. The methods analyzed by the researchers provide high accuracies of more than 85% across multiple test sites, and thus can be used as a pre-research work in the given area.

## 3. RESULT ANALYSIS AND CONCLUSION

From the above review into multiple domains of forest cover change detection, it can be analyzed that bi-temporal analysis of time series data has better result accuracy when compared with single dimension analysis of the data. Techniques like the error model based are novel in itself and must be analysed and explored further in order to improve overall accuracy of the time series data. Even techniques based on satellite imagery detection and leaf based forest cover detection, which are two extremes in terms of the source of data yield similar accuracies in detection and analysis of time series forest cover datasets. Researchers can work on multiple datasets in order improve the

accuracy of the time series analysis systems and due to the ease of availability of the data, this process can be put on fast track by researchers all over the globe. Datasets like Landsat, PALSAR, LiDAR, MODIS and others have proven good quality data for forest cover sets to the researchers for analysis. As an extension to the existing work, the researchers can use soft computing algorithms like fuzzy logic, genetic algorithm, particle swarm optimization, reinforcement learning based on machine learning and deep nets based on artificial intelligence in order to provide feedback based classification, which should improve the accuracy of clustering, classification and prediction in the system for time series analysis

**TABLE 1: Comparative analysis of various methods and datasets discussed**

| DATASET | METHOD | ACCURACY | COMMENT |
|---|---|---|---|
| Landsat [1] | Supervised machine learning based classifiers | More than 90% | • Can be used as input data for studies at local, global, or regional scales.<br>• Lot of indexes were needed to develop accuracy of classification. |
| Landsat[2] | Change vector analysis | 93.4% | • Can detect bitemporal forest changes and have good geometric quality data.<br>• Thresholding is required to separate change from no change. |
| MODIS time series data[3] | Linear classifiers | More than 60% | • Provides rich basis for monitoring land cover dynamics.<br>• Due to big data volume, lot of pre-processing is required. |
| Landsat and Corona data[4] | Support vector machine algorithm | 90% | • Achieves classification accuracy of about 95%.<br>• Requires more georegistration and classification methods. |
| LiDAR data[5] | Decision Tree algorithm | 91.25% | • Gives detailed classification and validation of forest characteristics.<br>• Requires hardware devices for leaf recognition process. |
| MODIS Time Series[6] | Distance metric based method | 77% | • Can incorporate land cover related information from nearby pixels to detect change.<br>• Have relatively high levels of commission errors. |
| ALOS PALSAR data[7] | ANOVA | 60% | • Serves as a base for satellite based forest cover change detection.<br>• Cannot work on different angles of images from satellite for the same area. |

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