UNIT 15

CHANGE DETECTION TECHNIQUES

Structure

15.1 INTRODUCTION

This unit mainly deals with various aspects of change detection techniques and factors responsible to understand the changes. In this unit, we will discuss about change detection necessity, their change agents, requirement of image processing change detection, steps involved for spectral change detection, and applications of change detection. You will also comprehend the significance of change detection.

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Expected Learning Outcomes

After studying this unit, you should be able to:

- define change detection and write the need of detecting changes;
- discuss basic factors/ agents responsible for change detection;
- discuss how the change detection techniques operate;
- describe various spectral change detection techniques; and
- explain the various application of change detection techniques.

15.2 CHANGE DETECTION

Human activity, sudden natural events, or long-term climatological or environmental trends can all lead to change on the earth's surface. One of the core uses of images and remote sensing is the detection of that change. In order to identify the kind, size, and location of a change, numerous raster datasets that were typically collected for the same area at various dates are compared. This could be done by detecting changes from one image to the next, across a stack of images, or throughout the course of an image time series.

Change detection is useful in many industries, but it also has non-commercial uses. This can be used, in particular, to monitor the progression and effects of flooding, forest fires, ongoing droughts, and other disaster and weather extreme phenomena. Finding differences between two satellite photos taken before and after an event is the foundation of remote sensing and GIS change detection approaches. GIS methods for change detection compare the spatial representation of two points in time and assess variations in the relevant variables.

Due to a number of issues, including the growing population, the destruction of natural resources, environmental pollution, land use planning, and others, environmental protection faces serious challenges. Unplanned changes in land usage are currently a significant issue. The majority of land use changes take place without a precise, rational strategy or any consideration of how they will affect the environment. Major flooding, air pollution in big cities, deforestation, urban expansion, soil erosion, and desertification are all effects of poor planning that didn't take environmental effects of development plans into account. A common result of incorrect land use change is desertification.

Remotely detected images are used in numerous applications nowadays for a variety of reasons. One of them is moving using high-resolution satellite symbolism of city boundaries. Over the past 50 years, rapid urbanization with changes in land use and spread has taken place in a number of urban centers around the world. The most important difficulty in this particular situation is the correlation between the extraction findings from these images and the pre-existing vector data. According to all indications, the availability of high-quality optical symbols appears to be exciting for geo-spatial database applications, particularly for the collection and maintenance of geodata.

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Remote sensing and image processing technology advancements in particular have made it possible to determine vast areas in detail and, in this regard, produce expanded and trustworthy recent data swiftly. As a result, it is possible to monitor the metropolitan regions' rapid development and establish methods to guide it. In this regard, automatic object extraction methods are now required for large-scale topographic mapping from the photos, identifying topographical changes, and updating the map data. Automatic object-based image analysis has been increasingly popular in recent years for remote sensing applications such as mapping from high resolution photos or building and updating GIS databases. Additionally, because the results of automatic object-based extractions are GIS-based, they may be included into GIS, queried, and subjected to a variety of strategic analyses.

Fig. 15.1: Change Detection in Satellite Dataset.

Definition: Identifying, describing, and quantifying variations between images of the same scene taken at different times or under various circumstances are the goal of change detection analysis, which includes a wide range of techniques.

15.2.1 Why Is Change Detection Necessary?

Understanding the linkages and interactions between human and natural events is crucial for better decision-making, and this requires timely and accurate change detection of Earth's surface features. In recent decades, remote sensing data have been employed widely as primary resource for change detection.

15.2.2 What does image processing's change detection entail?

Analyzing changes in satellite photos collected at two separate times is a process called "change detection." Different methods can be used to calculate the changes in these multi-temporal satellite photos.

15.2.3 The algorithm for change detection

Utilizing several temporal data sets, change detection entails quantifying temporal impacts. Satellite data is frequently employed when someone is interested in tracking changes over vast areas and at frequent intervals. The algorithms utilized have a significant impact on the outcomes of the digital analysis.

15.2.4 Factors for implementing change detection

The following prerequisites must be met before change detection analysis is put into practice: (1) accurate radiometric and atmospheric calibration or normalization between multi-temporal images; (2) precise multi-temporal image registration; (3) identical phenological states between multi-temporal images; and (4) detection of change

15.2.5 Operation of GIS-Based Change Detection

To derive insightful information, GIS software mixes spatial data with statistical data. Equipment like drones, unmanned aerial vehicles, or satellites are used to remotely perceive and collect the aforementioned spatial data. Numerous sources can be used to gather statistical data, and satellites, UAVs, and drones used for remote sensing can acquire geospatial data. Due to open data access, satellite change detection is becoming more and more popular today and is frequently the quickest and least expensive choice.

Now, if the data is gathered and examined over time, this provides us with a change detection dashboard to identify a given feature's aspect through time. This dashboard can then be used in a variety of ways, such as to comprehend changes in ice sheets and forest cover, among other things. It can recognize a certain feature's aspect in two distinct time frames. For instance, change detection can be used to track retail businesses to find any differences between the quantity of stores that opened five years ago and currently. Change detection can also be used to monitor the size, shape, and movements of a particular feature.

The applications of geospatial change detection are numerous. The technique is used to monitor changes in crop status, land usage, urban growth, vehicle mobility, glacier cracking, and other aspects of the environment. The discovery of manmade climate change in the world's oceans aids in understanding the extent of the issue and developing a successful response strategy.

GIS examines statistical and spatial data for change detection.

15.2.6 Change Agent

Change detection also benefits from knowing the "change agent," or what causes the change. The agent uses a variety of natural occurrences, like fire, insect infestation, storm, flooding, and drought, to describe natural changes. The term "agent" for anthropogenic changes refers to human-induced change, which is typically tied to land use and includes activities like urban development, farming, logging, and mining.

Urbanization, agriculture, insect attacks, fire, logging, mining, storms, and petroleum exploration and production are only a few examples of the change agents that have been the subject of most studies.

SAQ I

a) What is the goal of change detection?

b) Which analysis is popular in recent years for remote sensing applications such as mapping from high resolution photos or building and updating GIS databases?

c) What are the anthropogenic change agents?

15.3 TECHNIQUE FOR SPECTRAL CHANGE DETECTION

This section will help you comprehend how spectral change detection is implemented.

Images from two different dates are combined to create a new single-band or multi-band image that contains the spectral alterations in spectral change detection. To attribute the changes to certain land cover types, the resulting image needs to be further processed. These techniques are dependent on accurate picture registration and co-registration because they are based on pixel-wise or scene-wise procedures. The most critical aspect of these approaches' effectiveness is their ability to distinguish between change and no-change pixels. Use of statistical threshold is a typical technique for discrimination. To distinguish the area of change from the no-change area in this method, threshold borders must be placed carefully.

Following are some techniques for detecting spectral changes:

1. **Image Differencing**: Using this technique, a new change image between two dates is created by subtracting two co-registered image dates pixel by pixel in each band.
2. **Image Ratioing**: Using the same two co-registered image dates, each band is ratioed pixel by pixel. Ratio values that are close to 1 define the no-change area. Areas that have changed between two dates will have values that are higher or lower depending on the type of changes.
3. **Image Regression**: This technique takes the position that pixels at time t1 are linear features of pixels at time t2. It takes into account variations in pixel values from two dates' means and variances.

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4. **Change Vector Analysis**: A change vector of a pixel is the vector difference between the multi-band digital vector of the pixel on two different dates. The amplitude and direction of change from date one to date two are described by a spectral change vector. The output consists of two images, one of which shows the change vector's magnitude and the other its direction. If the magnitude of changes exceeds a certain threshold, the change is determined, and the type of change is indicated by the direction of the change vector.

5. **Vegetation Index Differencing**: In studies of vegetation, a ratio (sometimes referred to as a vegetation index) is employed to emphasize spectral contrasts between vegetation's strong near-infrared reflectance and the chlorophyll-absorption band (red portion) of the spectrum. Ratio Vegetation Index, Normalized Vegetation Index, and Transformed Vegetation Index are examples of common vegetation indices.

6. **Multi-date Principal Component Analysis**: In this method, two images from the same location taken at different times are superimposed and analyzed as a single image. The local alterations are revealed by the minor component images, while the major component images display the reflectance and radiometric variances (minor changes). This method is more useful than the post classification method for tracking rapid changes in land use and urban growth. On two photos from various dates, they performed a principal component analysis, and on the compressed PCA image, an interactive supervised categorization of land-use change was performed. The new method and the traditional post-classification methodology were compared using photos from two.

7. **Post-classification Technique**: In the post-classification method, each image is assigned a unique categorization and label. The area of changes is then extracted after a direct comparison of the categorization findings. This method employs both supervised and unsupervised classifications. The difficulty of adjusting for atmospheric and sensor changes between two dates is reduced to a minimum by individual classification of two image dates.

   The key drawback of this approach is the results of the categorization are accuracy dependent. Individual categorization errors result in the propagation of uncertainties in the change map, which produces erroneous information about changes in land use. The categorization methods, source image error, and change determination as the sources of uncertainty in change detection.

   They outlined the following three primary error factors for classification-based change detection using Maximum Likelihood (ML):

   a. Subjective data collection is utilized to gather training data;

   b. the ML classifier presumes that the probability distribution of each class is normal; and

   c. the method used to assess changes is not objective (based on number of uncertainties). The usual way to express the uncertainty in a categorized remote sensing image is as a confusion matrix (error).

Confusion matrix can be used to derive a number of error indicators, including error of commission.

8. On-screen Digitization: This technique is typically applied to scanned aerial photos and high-resolution data from distant sensors. This technique uses on-screen picture interpretation of high-resolution images to update inaccurate government urban infrastructure records.

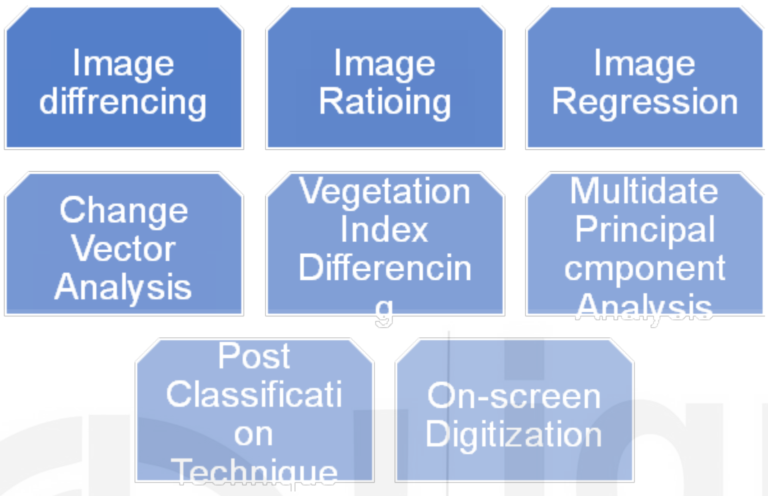

Fig. 15.2: Techniques for Spectral Change Detection

SAQ II

a) What is the Image ratioing?

b) Explain the Multi-date Principal Component Analysis.

c) What is the Change vector?

d) ...., ……………..., and ………………. are examples of common vegetation indices.

15.4 APPLICATIONS OF GIS CHANGE DETECTION

In this section, you shall understand various application for which change detection techniques are applied with the help of different GIS /RS software.

15.4.1 Land Use/Land Cover Application

The world's land resources are mostly inventoried via land use/land cover mapping. Remote sensing provides a method for quickly gathering and displaying data on land cover, whether it be on a regional or small scale. In recent years, geographic information systems and remote sensing have grown in significance as crucial instruments for the study of change detection at the district and city level. In order to maintain a sustainable ecosystem, it is required to monitor and identify changes in land use and land cover, which are crucial for understanding how human activities interact with the environment. Understanding the impact of man's activities on his natural resource base through time and from space is now essential. Data from Earth sensing satellites has grown increasingly important in recent years for mapping the Earth's features and infrastructures, managing natural resources, and researching environmental change.

An inventory level of data indicating the location, nature, and extent of change is provided by the satellite land cover change information. This information must be collected and incorporated into a database that allows for the identification and evaluation of the processes, outcomes, and interactions of change with the environment in order to effectively contribute to sustainable development initiatives.

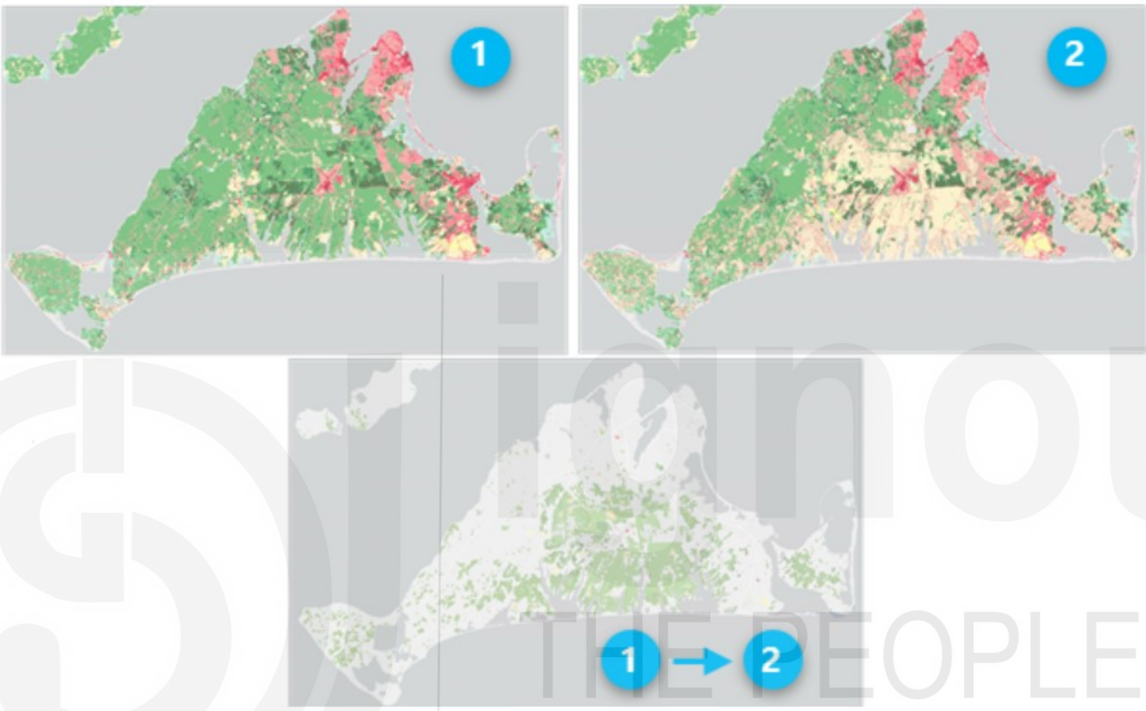

Fig. 15.3: Change Detection for Land Use/ Land Cover Application.

15.4.2 Coastal Conservation/Management

Coastal regions are susceptible to a variety of intricate natural processes, which inevitably result in both long- and short-term changes. These alterations can be categorized as shoreline retreat, sediment migration, water quality degradation, and coastal expansion. The degradation of the coastal socioeconomic value is directly impacted by the transformation of the coastal ecosystem, along with human life, infrastructure, property, and coastal land resources. It is necessary to continuously monitor environmental protection and sustainable development in coastal areas by gathering bathymetric data. The collection of bathymetric data is regarded as a key role in the monitoring system. Since the beginning of time, coastal regions have been crucial to humans. The majority of major cities are located along coastlines. Living by the coast accounts for about one-third of all human habitation.

Urbanization and population growth are increasing quickly in coastal areas due to the abundance of natural resources. Numerous construction initiatives in coastal areas have resulted in a variety of coastal dangers, such as soil erosion, seawater intrusion, coral bleaching, shoreline alteration, sedimentation, etc. Coastal landscapes are constantly changing. They are continuously changed by both natural and artificial processes. Understanding various coastal processes requires accurate coastline demarcation and surveillance. When employing conventional great surveying techniques, shoreline delineation for the entire coastal system is challenging, time-consuming, and occasionally impossible. Remote sensing and geographic information system tools have improved coastal geo-morphological investigations during the past few decades.

An important undertaking, shoreline change extraction and change detection analysis has applications in a variety of areas, including setback planning, hazard zoning, erosion-accretion investigations, regional sediment budgets, and conceptual or predictive modelling of coastal morphodynamics. Using conventional ground survey methods, shoreline delineation for the entire coastal system is challenging, time-consuming, and occasionally impossible. The challenges of isolating coastline position and detecting shoreline changes are being overcome by recent developments in remote sensing and GIS techniques. The most effective and dependable tools for mapping shoreline change today are those that have been developed via the use of remote sensing and GIS technologies.

The line of land-water contact is referred to as the shoreline.

15.4.3 Forest Fire Mapping

For a wide range of uses, spatially and temporally explicit knowledge about forest ecosystems is crucial, and Earth observation has developed into a crucial tool for managing forests and keeping track of the dynamics of their cover. With a heavy emphasis on forests, forest change detection seeks to discover significant changes in the time series signal (e.g., illegal deforestation, wind throw, fire). The monitoring of forest fires, risk mapping, and the identification of potential zones have all benefited greatly from the application of EO data and other RS methodologies. Furthermore, it has become increasingly important to precisely analyze and track the health state of forests using high-resolution satellite photography. Sensors on EO satellites have been used to track changes in energy emission since the 1970s. The breadth and frequency of forest fires are now better monitored thanks to a new generation of satellite sensors and Unmanned Air Vehicle (UAV) technology, which has improved the synergy of existing and upcoming RS technologies. Satellite data sets are useful for near-real-time fire detection, monitoring, and the assessment of the burned areas due to their large-area repeating coverage and inexpensive cost.

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Fig. 15.4: Forest Fire.

15.4.4 Change Detection using UAV technology

Even while satellite imagery's spatial resolution has substantially improved over the past ten years, the data still may not be sufficient to detect moderate to minor coastal changes. Unmanned aerial vehicles (UAVs or drones), on the other hand, can deliver extremely high-resolution photos for a small region at a reasonable cost. A mapping tool for environmental monitoring has been using drones in recent years due to their agility and high-quality image capabilities. UAVs are a feasible alternative for gathering data from distant sensing for a variety of real-world uses. They offer digital images with the spatial and temporal resolution needed to get beyond some of satellite imagery and aerial photography's drawbacks.

Datasets generated by UAV remote sensing have such high spatial resolution (1–5 cm), allowing for highly precise mapping of landscape properties in two (2D) and three (3D) dimensions (3D). Instead, at the spatial resolutions typically attainable by manned aircraft (10-100 cm) and satellite systems (>50 cm), such minute changes cannot be distinguished. Additionally, the UAV systems' simple deployment and low operating costs enable frequent missions, producing on-demand information with extremely high spatial and temporal resolution. Remote sensing is still one of the most effective methods for identifying and keeping an eye on coastlines, and it plays a significant role.

15.4.5 Machine learning for Change Detection

In recent years, artificial intelligence has advanced greatly, sometimes approaching human precision. There are many options now that weren't there before thanks to the merging of AI and GIS. Agriculture, law enforcement, and storm forecasting are just a few of the fields where artificial intelligence, machine learning, and deep learning are assisting in understanding and managing. In its simplest form, artificial intelligence is the capacity of a machine to carry out operations that ordinarily call for human intelligence. This procedure is one that can be carried out using machine learning.

It employs algorithms to learn from the data and provide us with the necessary response. Spatial analysis may now be done at a higher level by employing Deep Learning tools on ArcGIS Pro, even if Machine Learning has long been a crucial component of GIS software in work tools like Classification, Clustering, Geographically Weighted Regression, etc. Commercial drone use has increased significantly in recent years, ushering in a new era of photogrammetry marked by great precision and a sharp decline in the cost of gathering airborne data. With this unexpected influx of data, we can now do novel and precise analytics on topics of interest by merging Machine Learning techniques with GIS technology.

15.5 TERMINAL QUESTIONS

1. What variables are offered by satellite data on land cover change?
2. What is referred as line of land-water contact?
3. …….. are a feasible alternative for gathering data from distant sensing for a variety of real-world uses.

15.6 SUMMARY

In this Unit, you have learned the following:

- Identifying, describing, and quantifying variations between images of the same scene taken at different times or under various circumstances are the goal of change detection analysis.
- Remote sensing and image processing technology advancements in particular have made it possible to determine vast areas in detail and, in this regard, produce expanded and trustworthy recent data swiftly
- Analyzing changes in satellite photos collected at two separate times is a process called "change detection." Different methods can be used to calculate the changes in these multi-temporal satellite photos.
- GIS examines statistical and spatial data for change detection.
- Urbanization, agriculture, insect attacks, fire, logging, mining, storms, and petroleum exploration and production are only a few examples of the change agents that have been the subject of most studies.
- Images from two different dates are combined to create a new single-band or multi-band image that contains the spectral alterations in spectral change detection.
- Image differencing, Image ratioing, Image regression, change vector analysis, Vegetation index differencing, Multi date principal component analysis, Post classification techniques and on-screen digitization are the techniques of spectral change detection
- Remote sensing provides a method for quickly gathering and displaying data on land cover, whether it be on a regional or small scale

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- Various application of change detection such as Land use/Land cover analysis, Coastal area management, Forest fire, change detection using UAV technology, Machine learning for change detection.

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15.8 FURTHER/SUGGESTED READINGS

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15.9 ANSWERS

SAQ I

a) Identifying, describing, and quantifying variations between images of the same scene taken at different times or under various circumstances are the goal of change detection analysis, which includes a wide range of techniques.

b) Automatic object-based image analysis has been increasingly popular in recent years for remote sensing applications such as mapping from high resolution photos or building and updating GIS databases.

c) The agents responsible for anthropogenic changes refers to human-induced change, which is typically tied to land use and includes activities like urban development, farming, logging, and mining.

SAQ II

a) Image ratioing is utilization of the same two co-registered image dates, each band is rationed pixel by pixel.

b) Multi-date Principal Component Analysis is analysis where two images from the same location taken at different times are superimposed and analyzed as a single image. The local alterations are revealed by the minor component images, while the major component images display the albedo (reflectance) and radiometric variances (minor changes).

c) A change vector of a pixel is the vector difference between the multi-band digital vector of the pixel on two different dates.

d) Ratio Vegetation Index, Normalized Vegetation Index, and Transformed Vegetation Index are examples of common vegetation indices.

Terminal Questions

1. An inventory level of data indicating the location, nature, and extent of change is provided by the satellite land cover change information
2. The line of land-water contact is referred to as the shoreline.
3. UAVs are a feasible alternative for gathering data from distant sensing for a variety of real-world uses.

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