A Survey of Remote Sensing and GIS Integration Method

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***Abstract:* - The focus of the current paper is to synthesize available literatures on the integration of remote sensing and geographic information system, specifically the methodological approaches. The first section gives the general background of the study. This was followed by a review on the principles of remote sensing and geographic information system. Then, the practical method for remote sensing and GIS integration was reviewed. This synthesis demonstrates that, the integration of remote sensing and GIS is mutually beneficial. For example, it indicates that, there has been a tremendous increase in demand for the use of remotely sensed data combined with GIS-based data including environmental and socioeconomic data.**

***Keywords:* GIS, GISc, images, integration, remote sensing, and spatial data.**

I. INTRODUCTION

There has been a far-reaching intensification in remote sensing application for a range of studies in the recent past. This is because remote sensing has over the years proved to be an infinite pool of earth related data [1]. Satellite remote sensing is a timely technological development in view of serious pressures on our natural habitat [2]. Moreover, the growing potentials of Geographic Information Systems make it feasible for computer systems to handle geospatial data more efficiently than before. Many literatures and empirical research indicates that, the integration of remote sensing (RS) and Geographic Information Systems (GIS) has received considerable attention for a wide range of studies in the past four decades including [3,4,5,6,7,8,9,10,11], and others.

Although remote sensing and GIS developed quasi-independently, the synergism between them has become increasingly apparent [12]. This synergy creates a connection between the image raster world, and the geospatial vector world. Today, GIS software almost always includes tools for display and analysis of images, and image processing software commonly contains options for analyzing 'ancillary' geospatial data [13]. Merging remotely sensed data with previously existing vector data has become an indispensable prerequisite for proficient management and monitoring of geographical phenomena. This incorporation is best realized in an effective system that is characterized with the potential to handle varied types of geospatial data. A Geographic Information System (GIS) is a system by which we can input, manipulate, maintain, analyze, and output multiple forms and layers of spatial data [14]. Also, the parallel advance in the reliability of GIS has permitted the interpretation of large quantity of data generated through remote sensing to address different environmental problems [7].

It is essential to incorporate remote sensing data and other types of geospatial data in GIS, most especially because cartographic data created in GIS are frequently static, most of which are acquired on a single occasion and then archived. Also, in addition to the fact that, remotely sensed data are used for correcting, revising, and maintaining GIS database, it is primarily a data collection technology, while GIS is a predominantly data handling technology. Of course, many tasks that are seldom achieved in remote sensing image processing systems are relatively easy in a GIS, and vice versa. The focus of the current synthesis of literatures is on integration of remote sensing and GIS techniques. In this context, integration covers the application of each technology to promote the other, as well as the application of both technologies, in performance, for modelling and decision-support.

II. PRINCIPLES OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM (GIS)

2.1 Principles of Remote Sensing

Remote sensing is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation [15]. It refers to the science and technology of acquiring information about the earth's surface (i.e., land and ocean) and atmosphere using sensors onboard airborne (e.g., aircraft or balloons) or spaceborne (e.g., satellites and space shuttles) platforms [16].

Remote sensors may utilize any of an array of physical energy distributions. By doing so, the interactions of electromagnetic radiation with the earth's surface measured by air-borne or space-borne sensors are used to collect data of interest in a given area and search data at fixed intervals to reveal the changes in the land- use/land-cover patterns [17]. For instance, optical instruments such as the photographic camera and multi-spectral scanner use electromagnetic energy distribution.

Generally, remote sensing is concerned with detecting and recording reflected or emitted electromagnetic energy coming from the earth or a target area in view of the remote sensing instrument (sensor). Remote sensing system is thus categorized into passive and active, based on origin of the electromagnetic radiation. Passive sensors use an existing source of energy either emitted or reflected from the earth or a target. Examples of passive sensors are: cameras, radiometers, television cameras, line scanners, spectroradiometer and thermal infrared detectors, etc. The energy source in passive remote sensing is independent of the recording instrument [15]. On the other hand, active remote sensing systems (such as Radar, LiDAR, Laser, and others) produce their own electromagnetic radiation of specific wavelength, as a part of the system.

2.1.1. Principles of Electromagnetic Radiation

The first requirement for remote sensing is to have an energy source in the form of electromagnetic radiation to illuminate the target (unless the sensed energy is being emitted by the target). Remote sensing relies on the measurement of electromagnetic energy reflected or emitted by the earth's surface [18]. Solar energy travelling in the form of waves at the speed of light (denoted as *c* and equals to 3 × 108 ms–1) is known as the electromagnetic spectrum [16]. Generally, electromagnetic radiation is produced due to the motion of an electric charge. Oscillation of the charged particles set up changing electric fields which induce changing magnetic fields in its surrounding medium. The changing magnetic fields further set up more changing electric fields and thus a chain reaction continues endlessly. Therefore, electromagnetic energy is characterized by electrical and magnetic fields that are perpendicular to each other [18], and to the direction of propagation through space.

Electromagnetic energy has a dual nature, and exhibits two properties-wave and particulate properties. Based on the wave properties, electromagnetic radiation can be thought of as a travelling wave and may be characterized by three principal parameters including velocity (c), wavelength (λ), and frequency (f). These parameters are related by the following equation:

$$C = \lambda f \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where

The velocity (c) is commonly known as the speed, the wavelength (λ) is the distance between successive crests of the waves, and the frequency (f) is the number of oscillations completed per second.

The particulate theory suggests that, electromagnetic energy is composed of photons or energy quanta, having particle-like properties such as energy and momentum. Photon has energy but lacks mass and charge. The energy of quanta is given as:

$$Q = hf \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where Q is energy of a quanta in joules (j), h is Planck's constant (6.626x10-34 js), and f is frequency in hertz (Hz).

2.1.2 Characteristics of Remotely Sensed Data

Each remote sensing system (sensor) has their specific characteristic called resolution, and offers disparate type of parameters on the observed objects. Resolution refers to the maximum separating or discriminating power of a measurement. It is a measure of the ability of a remote sensing system or sensor to distinguish between signals that are spatially near or spectrally similar. The success of data collection from remotely sensed imagery requires an understanding of four basic resolution characteristics, namely, spatial, spectral, radiometric, and temporal resolutions [19].

Spatial resolution is the ability to sharply and clearly define the extent or shape of features within an image [20]. It is related to the sensor characteristics that define the degree of spatial detail it provide about features on the earth's surface [21]. In analogue photography, the spatial resolution of photograph refers to the sharpness of the image [15,11], whereas digital image spatial resolution refers to the size of the individual physical sample unit on the ground that is sensed by a given detector at any instant in time [22], or the dimensions (in meters) of the ground area that falls within the instantaneous field of view (IFOV) of a single detector within an array or pixel size [19]. The instantaneous field-of-view (IFOV) defines the (nominal) angle, subtended at the sensor, over which the instrument records radiation emanating from the Earth's surface at a given instant in time. Generally, sensor spatial resolution may be described in terms of low or coarse, medium or moderate, fine or high, and very high resolutions [21], so as to indicate the degree of the surface feature or surface detail that a satellite sensor can classify.

Spectral resolution refers to the range of wavelengths or bands that an imaging system or sensor can detect. It offers the description regarding the capability of a sensor to define fine wavelength intervals. For example, AVHRR, onboard National Oceanographic and Atmospheric Administration's (NOAAs) Polar Orbiting Environmental Satellite (POES) platform, collects four or five broad spectral bands (depending on the individual instrument) in the visible (0.58–0.68 μm, red), near-IR (0.725–1.1 μm), mid-IR (3.55–3.93 μm), and thermal IR portions (10.3–11.3 and 11.5–12.5 μm) of the electromagnetic spectrum. The Landsat TM sensor collects seven spectral bands, including 0.45–0.52 μm (blue), 0.52–0.60 μm (green), 0.63–0.69 μm (red), 0.76–0.90 μm (near-IR), 1.55–1.75 μm (short IR), 10.4–12.5 μm (thermal IR), and 2.08–2.35 μm (short IR). Hyperspectral sensors (imaging spectrometers) are instruments that acquire images in many very narrow contiguous spectral bands throughout the visible, near-IR, mid-IR, and thermal IR portions of the spectrum. National Aeronautics and Space Administration (NASA) Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) collects 224 contiguous bands with wavelengths from 400–2500 nm. Another example of a hyperspectral sensor is MODIS, on both NASA's Terra and Aqua missions, and its follow-on to provide comprehensive data about land, ocean, and atmospheric processes simultaneously. MODIS has a 2-day repeat global coverage with spatial resolution (250, 500, or 1000 m depending on wavelength) in 36 spectral bands.

The finer the spectral resolution, the narrower the wavelength ranges for a particular channel or band [20]. Black and white films record wavelengths extending over much, or the entire portion of the electromagnetic spectrum. Its spectral resolution is fairly coarse, as the various wavelengths of the visible spectrum are not individually distinguished and the overall reflectance in the entire visible portion is recorded. Colour films are also sensitive to the reflected energy over the visible portion of the spectrum, but have higher spectral resolution, as it is individually sensitive to the reflected energy at the blue, green, and red wavelengths of the spectrum. Thus it can represent features of various colours based on their reflectance in each of these distinct wavelength ranges.

Radiometric resolution of an imaging system refers to its ability to discriminate very insignificant differences in energy or incoming radiance. The finer the radiometric resolution of a sensor the more sensitive it is to deciding small differences in reflected or emitted energy. Coarse radiometric resolution would record a scene using only a few brightness levels, that is, at very high contrast, whereas fine radiometric resolution would record the same scene using many brightness levels. For example, the Landsat-1 Multispectral Scanner (MSS) initially recorded radiant energy in 6 bits (values ranging from 0 to 63) and later was expanded to 7 bits (values ranging from 0 to 127) [16], while Landsat TM data are recorded in 8 bits; that is, the brightness levels range from 0 to 255.

Temporal resolution refers to the frequency of a satellite sensor to cover a particular location or region on the earth surface. Therefore, temporal resolution has an important implication in change detection and environmental monitoring. Sometimes the dynamics of interest take place during the course of a day, a week, or over a number of years. Many environmental phenomena constantly change over time, such as vegetation, weather, forest fires, volcanoes, oil spill, and so on. Many weather sensors have a high temporal resolution (e.g. the Geostationary Operational Environmental Satellite (GOES) has a temporal resolution of 0.5/h).

2.1.3 Remote Sensing Data Interpretation and Analysis

Remote sensing is the primary source for many kinds of thematic data critical to GIS analyses, including data on land use and land cover characteristics and surface elevation [23]. Themes can be as diversified as their areas of interest, such as soil, vegetation, water depth, and land cover [24]. Thematic information is frequently collected by using visual interpretation of satellite data or aerial photographs, or by digital image analysis. Moreover, remotely sensed data can be used to extract metric information by using the principles of photogrammetry. These data may include: location, height, and their derivatives, such as area, volume, and slope angle, etc. the data interpretation aspect of remote sensing can involve the analysis of photographs (images) and/or digital data [15].

2.1.3.1 Digital Image Preprocessing

Most digital image analysis methods are based on tone or colour, which is represented as a digital number (i.e., brightness value) in each pixel of the digital image [16]. Neighbouring pixels corresponding to one real object have the same or similar brightness value [25]. If the image analyst is able to spot and select the distorted pixel from the image, then, such pixel can be restored as an average value of neighbouring pixels. Furthermore, texture and contextual information, which describes the association of neighbouring pixel values has been used in image classification [24]. Before main image analyses take place, preprocessing of digital images is frequently necessary to prepare the image for onward analysis.

The principal goal of image preprocessing is to enhance data that suppresses undesired distortions or improve image features relevant for further processing and analysis task. Pre-processing of images commonly involves removing low-frequency background noise, normalizing the intensity of the individual particles images, removing or enhancing data images prior to computational processing [26], detection and restoration of bad lines, geometric rectification or image registration, radiometric calibration and atmospheric correction, and topographic correction [24].

2.1.3.2 Photographic/Image Interpretation and Photogrammetry

Photographic interpretation refers to the task of identifying objects, features, phenomena, and processes in photograph/image and judging their importance in the photograph. It is used to derive useful spatial information from photograph/image. This include: detection, identification, delineation, enumeration, and mensuration.

In order to achieve a good image interpretation, and a later digital image analysis, it is required that the expert or interpreter be familiar with the subject under investigation, the study area, and the remote sensing system available to him. Usually, a combined team consisting of the subject specialists and the remote sensing image analyst is required for a relatively large interpretation task. Critical factors considered in photographic/image interpretation are: tone, grey level, or multispectral grey level vector; texture; pattern; size; shape; shadow; and association.

Photogrammetry may be defined as the science, art, and technology of obtaining reliable information from photographs [27]. With advancements in computer and imaging technologies, and also software capabilities, the conventional analog photogrammetric method has been transformed into a digital technique. The digital approach uses contemporary technologies to generate accurate topographic maps, orthophotographs, and orthoimages are produced employing the principles of photogrammetry. Of course, the greatest progress in implementing an all digital photogrammetric system has been in the production of orthophotographs [28].

An *orthophotograph* is photographic copy, prepared from a perspective photograph, in which the displacements of images due to tilt and relief have been removed [29]. An *orthoimage* is the digital version of an orthophotograph, which can be produced from a stereoscopic pair of scanned aerial photographs or from a stereopair of satellite images [30]. The production of an orthophotograph or orthoimage requires the use of a digital elevation model (DEM) to register properly to the stereo model to provide the correct height data for differential rectification of the image [19].

2.1.3.3 Image Enhancement and Feature Extraction

Due to the limitations of image acquisition devices and external factors, the resolution of remote sensing images is not very satisfactory, so image enhancement techniques play a very important role in image analysis [31,32] as it improves the quality of the images so that the information contained in them could be extracted in a meaningful sense [33]. Image enhancement is the modification of an image to alter the visual impact that the image has on the interpreter in a fashion that improves the information content. Generally, enhancement distorts the original digital values; therefore enhancement is not done until the restoration processes are completed.

The major goal of feature extraction is to extract a set of features, which maximizes the recognition rate with the least amount of elements and to generate similar feature set for variety of instance of the same symbol. Feature extraction describes the relevant shape information contained in a pattern so that the task of classifying the pattern is made easy by a formal procedure. Feature extraction is an important step in the construction of any pattern classification and aims at the extraction of the relevant information that characterizes each class. In this process relevant features are extracted from objects/ alphabets to form feature vectors. These feature vectors are then used by classifiers to recognize the input unit with target output unit. Many potential variables may be used in image classification, including spectral signatures, vegetation indices, transformed images, textural or contextual information, multitemporal images, multisensor images, and ancillary data [24,16]. However, the use of too many variables in a classification procedure may decrease classification accuracy [34]. It is important to select only the variables that are most effective for separating thematic classes [16], especially when hyperspectral or multisensory data are employed [24]. Hyperspectral datasets typically offers the potential to generate detailed information about earth surface due to their substantial number of spectral channel. Yet, they are characterized by processing complexity and high data redundancy resulting from high correlation in the adjacent bands; data dimensionality equally necessitates a great number of training samples.

Many feature-extraction approaches have been developed, including principal components analysis, minimum-noise fraction transform, discriminant analysis, decision-boundary feature extraction, nonparametric weighted-feature extraction, wavelet transform, and spectral mixture analysis. Also, high resolution remotely sensed data are normally used as source for feature extraction such as aerial photograph. Moreover, accessible high resolution satellite imagery such as IKONOS and QuickBird, has demonstrated potency as source to obtain effective and efficient feature information with automated extraction approach.

2.1.3.4. Image Classification

The goal of image classification is to identify and portray, as a unique gray level (or colour), the features occurring in an image in terms of the object or type of land cover these features actually represent on the ground [21]. Classification procedure is to sort out all pixels in a digital image into one of several land cover classes (e.g., water, forest, residential, commercial, etc.) and to generate a thematic "map" [16] based on spectral information represented by digital numbers in one or more spectral bands.

Image classification is typically undertaken using multispectral data, based on the spectral pattern for each pixel in the data. The traditional methods employ the classical image classification algorithms, e.g. K-mean and ISODATA for unsupervised classification [35] or the maximum likelihood classification (MLC), minimum distance, artificial neural network, parallelepiped, and decision tree classifiers for supervised classification [24,36]. Unsupervised classification method uses a clustering-based algorithms to partition the spectral image into a number of spectral classes based on the statistical information inherent in the image. By contrast, a supervised classification method is learning an established classification from a training dataset, which contains the predictor variables measured in each sampling unit and assigns prior classes to the sampling units [37].

Although both the generation of orthoimagery and topographic normalization demonstrate a form of remote sensing-GIS integration, we currently see the most sophisticated types of integration manifested in digital image classification and modelling [23]. The principal goal of such work is to enhance information extraction and thematic mapping by means of 'data fusion' and 'multisource analysis.' A wide variety of methods for employing multi-source data in digital image classification have been developed. All may be viewed as attempts to exploit the long- recognized value of bringing to bear multiple sources of data (ancillary data and/or multiple types of imagery) on extraction of information from images (e.g., through image interpretation) and to invoke, to some extent, the reasoning and logic employed for most of a century in visual interpretation of images [19, 38].

2.2 Principles of GIS

2.2.1 Scope of Geographic Information System and Geographic Information Science

Application of Geographic Information System (GIS) is not limited to specialist, rather, almost everyone apply it daily even though the non specialists may be unaware of this fact. For instance GIS technology is involved in location of a place of interest, and in finding shortest route for driving, etc. The emergence of GIS in the mid-1960s reflects the advancement in computer technology and the influence of quantitative revolution in geography. GIS has evolved dramatically from a tool of automated mapping and data management in the early days into a capable spatial data-handling and analysis technology and, more recently, into geographic information science (GISc) [16]. GIS has been an extremely essential tool for natural resources management since the 1970s, and the commercial success since the early 1980s has also culminated in a progressively wider area of its application. Today, GIS has become a critical tool for crime analysis, agricultural planning, emergency planning, land records management, urban area analysis, market analysis, transportation planning and others. Thus, to give GIS a generally accepted definition is difficult nowadays [16]. GIS is computerized software that stores, retrieves, manipulates, analyzes and displays geographically referenced data sets, which can be used for different applications [39, 40]. It can manage two basic types of data known as geospatial data that define the location of a feature or object on the ground and attribute data that describe the characteristics of these features [40].

Geographic information science (GISc or GIScience) emanated as a focus of considerable academic attention in the few past decades. It is the basic research field that seeks to redefine geographic concepts and their use in the context of geographic information systems [41]. GISc is an information science that deals with the acquisition, modelling, management, presentation, and analysis of geographic information. It is a science of handling spatial data, and underpins any scientific research where the characteristics of places and spatial relationships between places are important for description, explanation, prediction, and strategic policy making. GIScience re-examines some of the most fundamental themes in traditional spatially oriented fields such as geography, cartography, and geodesy, while incorporating more recent developments in cognitive and information science [41]. It also overlaps with and draws from more specialized research fields such as computer science, statistics, mathematics, and psychology, and contributes to progress in those fields [41]. It supports research in political science and anthropology, and draws on those fields in studies of geographic information and society." [41].

2.2.2 Raster GIS and Capabilities

A raster model divides the entire study area into a regular grid of cells in specific sequence (similar to pixels in digital remote- sensing imagery), with each cell containing a single value [16]. The origin of the grid may be assumed either at North West or south west corner [42]. In the raster data structure, individual cells are used as the building blocks for creating images spatial entities and models. The raster model is a space-filling model because every location in the study area corresponds to a cell in the raster. A set of data describing a single characteristic for each location (cell) within a bounded geographic area forms a *raster data layer* [16], within which a set of neighbouring locations with the same value forms zones.. Each cell is identified by an ordered pair of coordinates (row and column numbers) and does not have an explicit topological relationship with its neighbouring cells [16]. Typically, a number of cells usually square, triangular, and hexagonal, etc, represent information. In raster format, a point is represented by a single cell, a line by connected series of adjacent cells of the same value, and an areal extent or polygon by closed series of adjacent cells of some value [29].

2.2.3 Vector GIS and Capabilities

Vector GIS is coordinate-based which used two-dimensional Cartesian (x, y) coordinates to store the shape of spatial entity based on the principles of Euclidean geometry. Also, the more advanced topological vector model, based on graph theory, encodes geographic features using nodes, arcs, and label points.

The Vector GIS is a function of the fundamental premise that all ground features or entities can be represented by any of the three basic spatial elements or a combination of all the basic spatial elements or locations of the ground features referenced by the coordinate system. The spatial elements are represented by points, lines, and polygons in the vector data model [43]. Point is the basic spatial entity representation; lines are produced by linking points with straight lines, and areas are defined by sets of lines. Vector data is used in GIS because of precise nature of its representation method, storage efficiency, the quantity of its cartographic output, and the availability of functional tools for operations like map projection, overlay and analysis [44].

2.2.4 Network Data Model

A network is a scheme of linear features that is characterized by the appropriate attributes for the flow of objects. Most common examples of networks are roads, public transit lines, railways, air routes, bicycle paths, rivers and streams, utilities networks, and others. Correct topology is of foremost importance for network analysis, but correct geographic representation is not so long as key attributes are preserved [45]. This is because a network is typically topology-based: lines (arc) meet at intersections (junctions or nodes), lines cannot have gaps, and lines have direction [46]. To apply a network data model to real world applications, additional attributes such as travel time, impedance (e.g., cost associated with passing a link, stop, centre, turn, etc), the nature of flow (i.e., one-way flow, two-way flow, close, etc.), and supply and demand must be included [16].

Applications areas of network data model is wide including shortest-path analysis and measuring accessibility, location-allocation analysis, transportation planning, spatial optimization, and others. Some network applications can be accessed via commands in GIS software. Yet, others require linking a GIS package to a discipline-specific software package, such as intelligence transportation system (ITS).

2.2.5 Object-Oriented Data Model

Object-oriented data model is a data model that utilizes objects to systematize spatial data, and store geometrical as well attribute data in a single system. The emphasis is that spatial features or real world are treated as a set of individual objects with associated properties and methods. Features are no longer divided into separate layers; instead, they are grouped into classes and hierarchies of objects [16], contrasting the georelational data model, which stores geometries and attributes of spatial features separately and uses feature IDs to link them [46]. Basic principles for explaining the structures of objects include association, aggregation, generalization, instantiation, and specialization, whereas those for explaining the behaviours of objects include inheritance, encapsulation, and polymorphism [30].

Object-based image analysis basically requires image segmentation, attribution, classification, and the ability to perform query and connect individual objects or segments in space and time. Thus, it integrates knowledge from enormous range of disciplines concerned with the creation and use of Geographic Information System. This exceptional spotlight on remote sensing and GIS distinguishes object-based image analysis from allied disciplines such as computer vision and biomedical imaging, where outstanding research exists that may significantly contribute to object based image analysis.

III. INTEGRATION OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS (GIS)

3.1 Methods for the Integration between Remote Sensing and GIS

With the advent of digital remote sensing systems and image processing software, the importance of remote sensing in GIS has expanded considerably [23]. Applications of remote sensing range from the use of orthoimagery as a GIS base layer, to the development of thematic data on land use and the generation of unique geospatial datasets via extraction of cartographic features such as buildings and roads from imagery [23]. [47] summarized four ways in which GIS and remote sensing data can be integrated: (a) GIS can be used to manage multiple data types; (b) GIS analysis and processing methods can be used for manipulation and analysis of remotely sensed data (e.g. neighbourhood or reclassification operations); (c) remotely sensed data can be manipulated to derive GIS data; and (d) GIS data can be used to guide image analysis to extract more complete and accurate information from spectral data.

3.1.1. Contributions of Remote Sensing to GIS

3.1.1.1. Extraction of Thematic Information

Thematic information can simply be seen as information about a specific class of land cover or land use. Satellite images can be digitally processed to produce a wide variety of thematic data for a GIS project [46] and other important applications. Information classes are the categories of interest to the users of the data, e.g., forest types, wetland categories, agricultural fields, urban land use, and others. These classes are the information that can be generated from remotely sensed data through image classification. Of course, the intent of the classification procedure is to categorize all pixels in a digital image into one of numerous land cover classes, or "themes" [21].These classes are not directly recorded on the images, but can be derive indirectly, using the evidence contained in pixel values recorded by each spectral band of the images.

3.1.1.2. Extraction of Cartographic Information

Extraction of cartographic information is a time consuming process in the case of visual interpretation. One of the most dependable sources of spatial information is paper map such as historic and thematic maps. However, the methods for recognition in maps are particularly challenging due to the complexity of map content [48,49] and the presence of both single and composite map elements [50]. Therefore, the use of remote sensing data source for cartographic information extraction has become inevitable.

Extraction of lines, polygons, and other geographic features has been achieved from satellite images through the use of pattern recognition, edge extraction, and segmentation algorithms [51]. Pattern recognition in cartographic documents aims at the delineation and extraction of spatial information and its incorporation into GIS as raster or vector data [52].

3.1.1.3. Remotely Sensed Data Used to Update GIS

Remote sensing data present the most cost effective resource for timely revision of GIS databases and maps. In the case of satellite remote sensing, this is most especially coming from its temporal characteristics. Satellite remote sensing offers an efficient and cost-effective method of acquiring up-to-date and accurate information, and is easily updateable with minimal ground and aerial survey [53]. Remote sensing also provides data input to GIS for conducting change detection. The basis of using remote sensing data for change detection is that, changes in land cover result in changes in radiance value, which can be remotely sensed [10]. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times [54]. Remote sensing change detection is now widespread due to its quick analysis processes, accurate results and visual spatial information. Also, remote sensing and GIS integration permits raster query in vector environment, and conduct analysis without the need for data format conversion and overlay. Image statistics within vector polygons then can be used to examine changes that have occurred and update maps [16].

3.2. Contributions of GIS to Remote Sensing

It would have been perfect to exploit remotely sensed data without the necessity to obtain any other type of data for anykind of support. Nevertheless, ancillary data are normally constantly essential for complete and precise operations involving the application of remotely sensed data. GIS data are useful in enhancing the functions of remote sensing image processing at various stages including selection of the area of interest for processing, image preprocessing, and image classification, as well as in organizing field/reference data for remote sensing applications. Details of these are indicated in the following subsections.

3.2.1. Use of Ancillary Data for Selection of the Area of Interest

Selection of the area of interest (AOI) from the satellite imageries of period of any study is normally undertaken in order to restrict analysis to the area of study. The conventional approach is by using the digitized or existing shapefile map of the study area to mask and clip the image [53]. This is achievable in today's image processing software (e.g., ERDAS IMAGINE). This makes image processing much more efficient because of faster processing times, no need to store intermediate data, and a reduction in data integrity problems. However, there are a few practical and conceptual problems in using ancillary data in remote sensing image analysis [38]. It is preferable that, ancillary data should be compatible with remote sensing imagery in terms of scale, level of detail, accuracy, geographic reference system, and date of acquisition. Sometimes ancillary data are presented as discrete classes (i.e., nominal or ordinal data), whereas remote sensing data represent ratio or interval data [16]. Therefore, to achieve optimal result, the compatibility between the two types of data must be addressed.

3.2.2. Use of Ancillary Data in Image Preprocessing

Image preprocessing may include the detection and restoration of bad lines, geometric rectification or image registration, radiometric calibration and atmospheric correction, and topographic correction [24]. At the stage of geometric and radiometric correction, GIS data such as vector points, area data, and DEMs are used increasingly for image rectification [51]. Accurate geometric rectification or image registration of remotely sensed data is a prerequisite for a combination of different source data in classification process [24]. The impacts of varying topography on the radiometric characteristics of digital imagery can be corrected with the aid of DEMs [51]. Variables generated from DEM can be used for topographic correction or normalization in order to eliminate the impact of terrain on land-cover reflectance can be removed

3.2.3. Use of Ancillary Data in Image Classification

Generating the accurate information from remotely sensed data investigation often requires some ground truth data most importantly due to environmental and atmospheric variations in space and time. Ancillary data have long been useful in the identification and delineation of features on manual interpretation of aerial photos; for digital remote sensing, ancillary data must be incorporated into the analysis in a structured, formalized manner that connects directly to the analysis of remotely sensed data [38]. Ancillary data may include cartographic, topographic, historical, climatological, soil, road, census, and others. The use of ancillary data in image classification may enhance the classification in the three main stages of classification, that is, pre-classification, during classification, and post-classification sorting. For instance, topographic data are used as a stratification tool in pre-classification, as an additional channel during classification, and as smoothing means in post-classification [55]. Topographic information improves the image classification accuracy when the study is performed on a local scale, while climatological data are more useful on regional or continental scales.

3.2.4. Use of GIS to Organize Field/Reference Data for Remote Sensing Applications

In addition to enhancing the functions of remote sensing image processing at various stages, GIS technology provides a flexible environment for entering, analyzing, managing, and displaying digital data from the various sources necessary for remote sensing applications. Many remote sensing projects need to develop a GIS database to store, organize, and display aerial and ground photographs, satellite images, and ancillary, reference, and field data.

IV. CONCLUSION

Remote sensing and Geographic Information Systems (GIS) make up the two most important tools of Geographic Information Science (GISc). The increasing accessibility of remote sensing technology has opened a vista for investigating and monitoring the real world in ways that could only be imagined in the past. For the last couple of decades, the application of remote sensing is not only revolutionized the way data have been collected but also significantly improved the quality and accessibility of important spatial information for conservation and management of natural resources. Also, the speedily growing GIS technology is a guide to deep understanding for historical, conceptual and practical uses of remote sensing.

Having realized a great deal of benefits and wide applications of remote sensing and GIS, the remote sensing and GIS communities have to continue to aim their enthusiasm at the integration between remote sensing and GIS. Of course, this paper shows that, remote sensing products are attractive to GIS database development because they can provide cost-effective large spatiotemporal data in a raster data format that are ready for input into a GIS and convertible to a suitable data format for subsequent analysis and modelling applications. On the other hand, GIS data are useful in enhancing the functions of remote sensing image processing at various stages including selection of the area of interest for processing, image preprocessing, and image classification, as well as in organizing field/reference data for remote sensing applications

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