Springer Water

Amin Shaban *Editor*

Satellite Monitoring of Water Resources in the Middle East

Springer

Springer Water

The book series Springer Water comprises a broad portfolio of multi- and interdisciplinary scientific books, aiming at researchers, students, and everyone interested in water-related science. The series includes peer-reviewed monographs, edited volumes, textbooks, and conference proceedings. Its volumes combine all kinds of water-related research areas, such as: the movement, distribution and quality of freshwater; water resources; the quality and pollution of water and its influence on health; the water industry including drinking water, wastewater, and desalination services and technologies; water history; as well as water management and the governmental, political, developmental, and ethical aspects of water.

Amin Shaban
Editor

Satellite Monitoring of Water Resources in the Middle East

Springer

Editor
Amin Shaban
National Council for Scientific Research
Beirut, Lebanon

ISSN 2364-6934 ISSN 2364-8198 (electronic)
Springer Water
ISBN 978-3-031-15548-2 ISBN 978-3-031-15549-9 (eBook)
https://doi.org/10.1007/978-3-031-15549-9

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

Water and environmental scientists should pay attention to the recent book of Professor Amin Shaban, senior experts in the field of water resources management and satellite remote sensing.

I proudly state that this book is a unique international reference in the sense that new information is presented for the first time, for the scientific research community related to remote sensing applicability to water resources management sustainability.

This book represents a comprehensive overview of the hydraulic situation in the MENA region and proposes solutions, direct technologies applications of advanced systems within the scope of Sustainable Development Goals. It also covers various key areas and fields of interest such as the fundamentals of satellite remote sensing, water resources in the Middle East, MODIS Satellite Images, and TRMM Products to Compare Rainfall and Streamflow along the Coastal Rivers of Lebanon, Landsat Satellite Images for Lineaments Detection: a Tool to Identify Groundwater Productivity in Lebanon...among many other areas of expertise.

During the regional complexity, Prof. Shaban's contribution is fundamental since it puts within our reach effective realistic combinations that are necessary to understand the various facets of hydraulic reality in the MENA region.

Moreover, the methodological and scientific depth covered by this book is very enriching since it facilitates the flow of facts and knowledge in the hydraulic field and its related components. It demands great intellectual ability to document and propose more than 20 articles presented by prominent scientists in the field and propose solutions based on extremely sensitive technological tools, helping Water leaders to a better Management of this vulnerable resource.

This publication provides guidance for the researchers around the world while ensuring an easy access to real data, authentic information, documented approaches, and technical procedures that are all required for an adequate integrated water resources management.

In addition to this, the analysis presented in various chapters of this book is specifically written while taking into consideration the decision makers and while highlighting the necessity of improving the global understanding of water resources around the world. It also describes the numerous studies that were done at the international level to review and face the multiple challenges that are threatening future generations' hydraulic security.

Once again, we discover throughout this publication that strategic alliances, cooperation, and dialogue between water actors are necessary to achieve the sustainable development goals and to guarantee therefore an everlasting water peace.

Readers will clearly sense the complexity of sustainable water management in the MENA region and the constant challenges of water adaptation policies in order to face extreme events phenomenon caused by the global changes impacts.

At the end, I can state that Professor Amin Shaban's efforts in publishing this book were impressive and noteworthy.

It is a striking addition to the already existing knowledge.

It is an asset for water experts, researchers, and policy makers.

Fadi Georges Comair
Director of the EEWRC-CYPRUS INSTITUTE
Chair of UNESCO'S IHP COUNCIL
(2019–2021)

Preface

The Middle East Region with a surface area of more than 7 million km^2 (i.e., 5% of the total area of the Globe) is inhabited by more than 4.4 % of World's people who live in diverse geographic locations including coastal zone, mountains, and deserts. This region is almost situated between three continents and constitutes a significant geographic zone for the entire World. The Middle East Region encompasses 18 countries where 13 of them belong to the Arab Region and comprising 62 % (285.19 million people) of the total population and 66.5% (4848674 km^2) in the surface area. The Middle East Region is mainly an arid to semi-arid zone with some sub-humid mountainous localities; and thus, it is the most water-poor region where the average annual precipitation is less than 200 mm besides a potential evapotranspiration exceeding 2000 mm per year.

Lately with the exacerbated population growth and its relevant increase in human activates, notably in the agricultural sector resulted in abrupt water shortage and water became a valuable commodity; and therefore, the per capita does not exceed 100 m^3/year in many instances in this region. The changing climate is another main reason in water scarcity in the Middle East Region, and all obtained studies confirmed abrupt oscillations in the climatic conditions which have been changed into torrential rain patterns and recurrence of climatic extremes accompanied with considerable increase in temperature. This has been reflected on the socioeconomic aspects of the entire region, while the geo-political conflicts added another challenges on water resources and especially on shared water resources.

The countries of the Middle East Region are addressing the problem of water scarcity with different tools and measures. Therefore, some of these countries, even with minimal water availability, can manage their supply/demand by adopting non-conventional water resources. While, other Middle Eastern countries, even with considerable water availability, are still witnessing water shortage and the supply/demand is still imbalanced and this has been reflected in several shortages of many other vital sector, notably the agriculture and energy sectors.

Beside the existed challenges on water resources in the Middle East Region, the applied measures to conserve the available resources and to adapt to the changing climatic conditions are inadequate to resolve the problem, plus the mismanagement in many instances plays a negative role in securing pure water with sufficient amounts.

In this regard, the role of the scientific research is significant and it can assist in putting water policies and strategies in the Middle East countries. There are several studies and research projects applied on water resources assessment in this region, including monitoring and exploration approaches. Recently, this studies have been supported by the use of advanced techniques with a special emphasis on the use of space techniques where satellite images with different spatial and temporal resolution. The history of monitoring satellites in the Middle East has been come to light since the beginning of 1970s, at the time when new water resources in the Middle East Region have been explored and it puts the initial step forward to adopt these techniques which proved its creditability to be a useful tool in studying water resources and the relevant themes. This includes: identifying hydrogeological clues for groundwater reservoirs, monitoring water infiltration to subsurface rocks, monitoring the changes in groundwater level, delineating surface water basins, detecting groundwater seeps to the sea, identifying fracture systems and their relationship with groundwater flow/storage, and many other applications.

The authors in this book introduce a number of case studies obtained by outstanding experts. It has been dedicated to be used by a miscellany of audiences including academics, scientific researchers, experts and decision makers, universities and research centres, as well as to the national institutes belonging to water sector.

Beirut, Lebanon Amin Shaban

Contents

Fundamentals of Satellite Remote Sensing

Amin Shaban

1 General Overview

The term "remote sensing" was first mentioned in the early 1960s to describe tools for observing the Earth from space, when initially the classical capturing of aerial photographs has been found and the camera was the first used sensor. Hence, observing objects on Earth's surface from height requires energy interaction between the object and the sensor. The energy signal emitted from objects on terrain surface is detected by space sensors, and it is either stored in memory on board the satellite system or transmitted to ground receiving stations for further processing.

Normally, the human vision represents a sophisticated remote sensing process within a unified system, providing great spatial and color advantages. Thus, digital (electronic) processing of satellite images extends our capability to integrate combined spatial information from different sources. The first mission that officially incorporated photography for potential geological and meteorological applications from space was the Gemini Titan in 1965 (Chuvieco 2020).

There are numerous types of satellite images retrieved today, and the type of these images is attributed to many digital and physical characteristics, such as spatial resolution, orbiting time, properties of the captured rays from objects, plus many other characteristics. Therefore, remote sensing is considered as geo-spatial data source which can cover large areas wherever they are. It is a significant tool for monitoring and capturing observations with least cost and time saving. Remote sensing, notably by using satellite images, has occupied large applications and it is included in many academic centers, ministries, and many other institutions.

A. Shaban (✉)
National Council for Scientific Research—Lebanon (CNRS-L), CNRS-L, P.O. Box 11-8281, Beirut, Lebanon
e-mail: geoamin@gmail.com

A. Shaban (ed.), *Satellite Monitoring of Water Resources in the Middle East*,
Springer Water, https://doi.org/10.1007/978-3-031-15549-9_1

From remote sensing, maps are usually the target products, because they can be easily read and even understood by non-specialists. They are supplementary documents for decision makers as well who rely mainly of maps to elaborate strategies and plans, notably in the view of the economic development and resources sustainability.

The beginning of topographic maps production has been joined with the use of stereoscopic photographs and lately with satellite images where the latter is able to produce topographic maps with high accuracy. Whereas satellite remote sensing has been used for topographic mapping purposes since the launch of ERTS-1 in 1972 (Dixon-Gough 1994).

The earliest aerial photograph, which was taken from a balloon and entitled "Boston", was taken in 1860. Therefore, photography and photogrammetry sciences have been developed, and then commonly used especially for the military purposes during the World Wars I and II. Therefore, aerial photos represent the beginning of Remote Sensing era when the first recorded photograph was taken from an airplane by Wilbur Wright in 1909. Later on, aerial photos with a miscellany of specifications are interpreted by stereoscopes. This resulted in the development of science of photogrammetry which enables applying analysis and measurements for the Earth's surface.

Recently, the use of satellite images and the relevant and supplementary remote sensing tools (e.g. drones, color aerial photos, geo-information systems, etc.) has become widespread and applied for several applications, including the assessment and exploration of natural resources and monitoring and diagnose of the surficial processes whether the physical/or natural ones.

Satellite remote sensing is a vast topic with applications on terrain analysis, physical oceanography, land/ocean ecosystem, and the science of cryosphere atmospheric and near-earth space. Hence, learning the entire field would require studying perhaps a dozen books on the topic, and lately many researchers with other field than remote sensing have been involved in this field and dedicate their jobs for remote sensing while their background knowledge is totally different. This is also the case with the applications of geo-information systems and the related geo-spatial data extraction and analysis.

The fundamentals of satellite remote sensing requires understanding several basic information, concepts and definitions. Here are some basics definitions and concepts relevant to satellite remote sensing:

- Electromagnetic radiation is energy propagates through space or through any media in the form of electromagnetic waves. The characteristics of electromagnetic radiation vary in the wavelength. The entire range of wavelengths is called the electromagnetic spectrum, which is classified into different regions of the spectrum, depending on their characteristics. Visible light is an example of these spectral bands. Radio waves, infrared rays, and ultraviolet rays are other familiar forms (Fig. 1).
- Satellite Remote Sensing is a recent technology for obtaining geo-spatial information about the features on surface of the Earth with special (and different) sensors mounted on satellites.

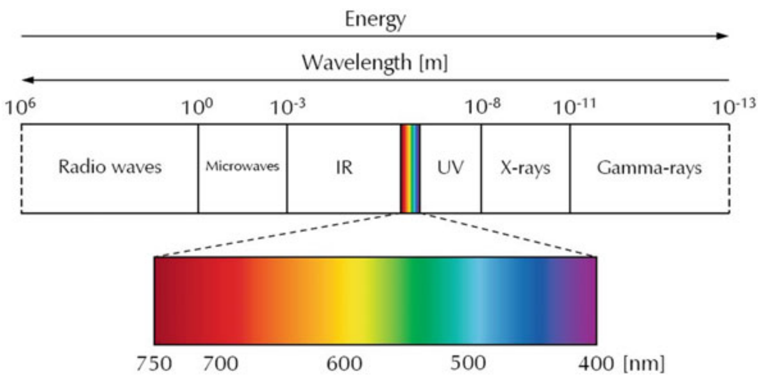

Fig. 1 The electromagnetic spectrum (UoB 2021)

- Each type of these features, absorbs and reflects solar radiation in a characteristic manner.
- Remote sensors on-board satellites do not capture all of the electromagnetic radiation that reaches from their source on Earth to satellites. Mainly due to technological and economic constraints, only some limited regions or bands of the electromagnetic spectrum are selectively detected by remote sensors. Thus, potential applications of a certain remote sensor depend on the number of bands it can be detected and the range these bands are located in the electromagnetic spectrum (Shimizu 2011).

  According to spectral signatures from sources, there are two main Remote Sensing sensors: passive and active (or microwave). Passive sensors detect the electromagnetic radiation naturally emanating from the surface of the Earth. Typically, they are camera and electro-optical sensors. While, active sensors, such as radar and laser, transmit energy for illumination which is directed toward the target object, and then it capture the reflected radiation reflected from that target.
- Images can be as raster or vector ones. Hence, raster image is a pixel-based image, and it is also called "bitmap", which represents a grid of individual pixels that collectively compose an image (Fig. 2). While, vector image refers to vector graphics that are based on mathematical formulas that define geometric primitives such as polygons, lines, curves, circles and rectangles (Fig. 2).

Remote sensing is also attributed to the type of radiation received by sensors and the ranges wavelengths, as follows:

- Visible and Reflective Infrared RS,
- Thermal Infrared RS,
- Microwave (or radar) RS.

Space techniques, as new innovative tools, have several types where numerous aspects of sensors are mounted of shuttles (platforms carrying satellites) to compose satellites travelling in space along define orbits. There are tens thousands of satellites

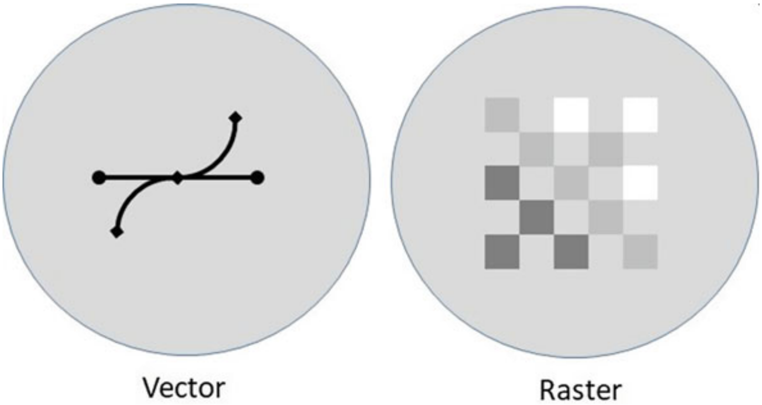

Fig. 2 Simplified illustration for raster and vector images

have been lunched into space moving around the Earth, where the largest part of them is not operating.

Two main types of orbits satellites follow, these are the communication satellites and land (or Earth) observatory satellites. Hence, communication satellites connect between different sources and receives all over the globe (e.g. navigation, TVs, GPS, radios, etc.). Observatory satellites are dedicated to monitor Earth's surface by acquiring observations and images covering the marine and terrestrial environments. Thus, satellites follow two global orbital trends; the geostationary satellites follow WE orbit, and it is mainly used for meteorological and communication purposes; however, land observatory satellites are orbiting in the near-polar orbit (Fig. 3).

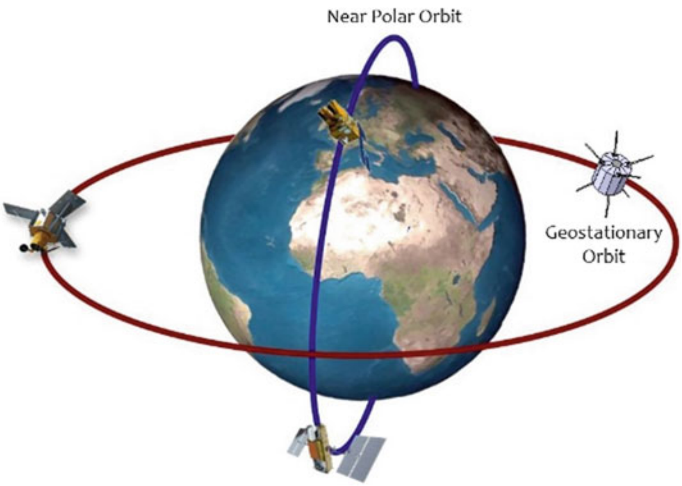

Fig. 3 Polar and geostationary satellite orbits (SEOS 2021)

The flight characteristics of space shuttles are important for the resolution of the acquired geos-spatial data; however, the optical and technical characteristics of the fixed sensors on satellites are most significant in this concern. That is why some satellite images with low-altitude shuttles have less spatial resolution that other satellite images with high-altitude shuttles. The most known flight altitudes of shuttles for inquiring geo-spatial data are: (1) satellites (altitude: 500–900 km), (2) space shuttle (altitude: 185–575 km), (3) high-latitude flying aircraft (altitude: 10–12 km), (4) moderate-latitude flying aircraft (altitude: 1.5–3.5 km) and (5) low-latitude flying aircraft (with altitude below 1 km).

2 Characteristics of Satellite Images

Recently, there are many satellite systems orbiting around the Earth and collecting images for different themes. Each type of satellite data offers specific characteristics that make it more or less appropriate for a particular application (Eastman 2001).

The first lunched remote sensing satellites are: Sputnik in 1957; Explorer in 1958 and Corona in 1960. They were used in many new applications. Later on, these applications were progressed with the advancements of the space techniques. Hence, remote sensing occupies a variety of applications including assessment, monitoring and exploration. This has been extended to (but not limited) water resources, agricultural, natural hazards, marine environment, pollution, change detection, etc.

Usually, determining the specifications of a satellite image is prerequisite step in order to select the type of satellite images that fit with the purpose of any study. It is often happened that satellite images available do not fulfill the requirements of a specific study. Therefore, several specifications characterize satellite images and should be primarily known by the investigator. The most significant ones are:

1. Resolution:
   Resolution of an image refers to the number of pixels displayed per inch of an image; however, this in a broad sense describes the spatial resolution, but there are other types of images resolution which are represented by spatial, temporal, spectral and radiometric resolution.

   - Spatial resolution
     It is the size of a pixel size recorded in a raster images. While, the pixel is the smallest detectable element in the image, and it enables distinguishing features. The pixel in a satellite image is a function of discriminating objects on Earth's surface. Hence, there are supportive tools act in the clarification on the images such as lens antennae, display, exposure, processing and many other specifications. Therefore, low-resolution images occupy large pixel size, and thus small objects will not be able to be clearly observed (Fig. 4). Hence, sensors mounted satellites result diverse spatial resolution.

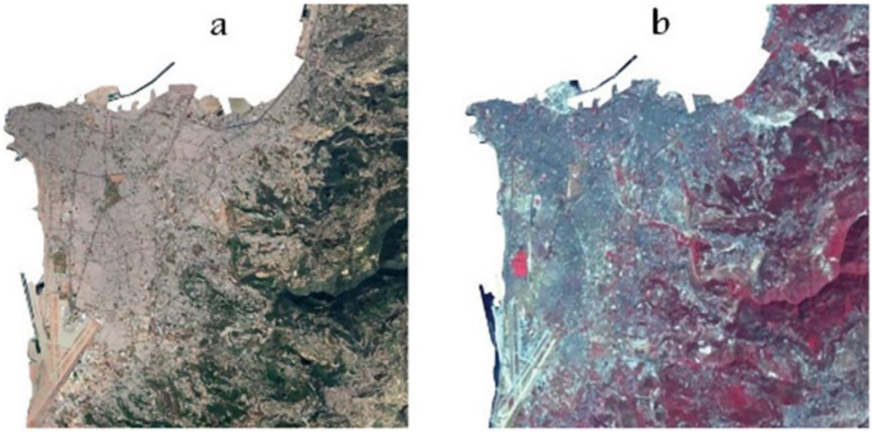

Fig. 4 Two satellite images with different spatial resolution showing Beirut area, Lebanon. **a** Aster 2019 (15 m); **b** Landsat 7, 2018 (30 m)

- Temporal resolution
  This is also described as revisit time, and it is the time needed to revisit and acquire image/s for the exact same location on Earth's surface. However, the amount of time depends on the orbital characteristics of the satellite shuttle as well as the characteristics of sensor fixed on the shuttle. The temporal resolution is high when the revisiting delay is low and vice-versa. Temporal resolution is usually expressed in days for most satellites (Théau 2008).
  The temporal resolution of a satellite image does not affected by the spatial, spectral or radiometric resolution. For example, Landsat images with 30 m spatial resolution and Aster images with 15 m spatial resolution both require 16 days revisit the same location on Earth's surface. While, Spot-6 images with 6 m spatial resolution requires 26 days' revisit time.
- Spectral resolution
  The spectral resolution represents band range or band width that recorded by the sensor. It is also the ability of a sensor to identify fine *wavelength* intervals. Thus, the finer the *spectral resolution,* the narrower the *wavelength* range for a particular channel or band. For example, the satellite image of Landsat sensor has seven bands, where it includes infrared spectrum, with a spectral resolution ranges between 0.7 μm and 2.1 μm. While, the sensor of Aster satellite image has 14 spectral bands where three of them are in the visible band range and 11 in the infrared band range.
- Radiometric resolution
  This is measured in bit, and it is corresponds to the ability of a sensor to distinguish grey-scale within the same *spectral band* of differences in the electromagnetic energy reflected by ground surfaces. Therefore, a sensor with finer radiometric resolution is able to record more significant intensity levels. The more bit an image has, the more grey-scale values can be stored, and,

Fig. 5 The relationship between bit and the grayscale values (American Cinematographer 2005)

thus, more differences in the reflection on the land surfaces can be spotted. Hence, one bit stands for a sensor that knows only black and white. 2 bit equals 4 grey-scale values and 4 bit 16 values (Fig. 5). The convert equation is as follows:

$$2 \; to\, the \;\; Power\, of \;\; Bit \; = number\, of \;\; Grey - Scale \;\; Values$$

2. Multi-look imagery:
   Several satellite-based imaging systems have the ability to acquire images at different view angles, where more than one sensor are mounted on the satellite platform to produce stereo satellite imaging (or 3-D imagine). In this process, two pictures of an object are taken from slightly different angles allowing for depth to be perceived when viewing the images. Typical of these satellites are: Spot, Ikonos, Quick-bird and many other satellites. In remote sensing applications photographs of Earth's surface are taken and 3D topographic maps and computer models can be created using the stereo images.
   In this regard, there is a tradeoff between spectral and spatial resolution when designing a system (Galbraith et al. 2005). In multispectral systems, each detector occupies different spectral bands. Hence, the increase of image resolution is designed through a capable sensor system for acquire images at a lower resolution and use the sensor system's pointing capabilities to allow collection of multiple low-resolution images within a short time span as the sensor travels over a target area. Then, image processing methods to fuse the multiple low-resolution images into a single high resolution image may be used (Borman and Stevenson 1998).
3. Swath width:
   Swath width describes the images area that represents the actual surface area on the Earth's surface. It depends on the specifications of the sensor in sizing the imaged observation, which is also named as "image scene". In aerial photographs, swath width is usually a function of flight altitude; but this is not the case for images retrieved by satellites which depend mainly on the specifications of the sensor.

Most satellite images with large size scene (swath width) are found with low spatial resolution. For example, Modis satellite images have swath width of 2030 km

Table 1 Example of commonly used land observatory satellite images (Al Saud 2020)

Satellite	No. of bands	Spatial resolution (m)	Temporal resolution (days)	Swath width(km)
Worldview-4	6	0.31	1.7	13.1 × 13.1
Geo-Eye	5	0.50	2.8	15.2 × 15.2
Kompsat-6	6	0.50	28	30 × 30
Quick-Bird	5	0.61	1–3	16.5 × 16.5
IKONOS	5	0.82	3	11.3 × 11.3
Rapid-Eye	5	5	5.5	77
Sentinel-1A	13	5	6	250
SPOT-7	4	1.5	26	60 × 60
Aster	14	15 VNIR, 30 SWIR, 90 TIR	16	60 × 60
IRS 1D	4	23	5	70 × 142
Landsat 7 ETM +	8	30, 120 thermal,15 pan	16	183 × 183
Landsat 8 OLI-TIRS	14	30, 100 thermal,15 pan	16	183 × 183
MODIS	36	250, 500, 1000, 2000, 4000	Twice/day	2030 × 1354
AVHRR	4	1.1 km	Twice/day	3000

× 1354 km, while they are characterized by low spatial resolution that starts from 250 m; whereas AVHRR has swath width of 3000 km and 1.1 km spatial resolution.

It is obvious that the specifications of an image, notably those retrieved by satellites, must be primarily identified while selecting the type of image to be processed for define purposes as it is shown in Table 1.

3 Processing of Satellite Images

Satellite image processing is a significant field in research and development. It consists of the images of earth and satellites acquired by artificial satellites. Primarily, the photographs are captured in digital form and then they are processed by the computers to extract the geo-spatial information required. Further on, a number of statistical and interpolation approaches are applied to the digital images and after processing the various discrete surfaces are identified by analyzing the pixel values.

The available digital raster images of spectral reflectance data is resulted from the solid state multispectral scanners and other raster input devices. The advantage of having digital raster image data enables elaborating several computer-based analysis. Hence, the efficiency of acquiring clear and comprehensive observations and data analysis from satellite images is mainly based on the optical and spectral characteristics of these images, and this include identification of terrain features with a comprehensive observation, monitoring and change detection, environmental and coastal assessment, etc.

As a typical example illustrated by Al Saud (2020), in that the tracking Earth's surface by Ikonos satellite images enables distinguishing objects with approximately 0.82 m × 0.82 m size, and this is more likely to watch these objects from approximately 100 m above terrain surface. This virtually means that human can fly over any area and clearly observe all objects exceed 0.67 m^2 (0.82 m × 0.82 m).

There are two main components must be ready in order to start the analysis of the satellite images. These raw data (in digital form) and the suitable software for image processing. For this purpose, there a miscellany of software types used for satellite images processing, with a special focus on:

- *ECognition*: Produced by Trimble Inc. California, USA.
- *ENVI*: Produced by: IBM. Colorado, USA.
- *ERDAS Imagine*: Produced by: Lucia, Georgia, USA.
- *QGIS*: Produced by Wikimedia Foundation. San Francisco, USA.
- *PCI* Geomatics: Developer of Geomatica, Toronto, Canada.
- *ILWIS*: Produced by ITC, Enschede, Netherlands.

Each software occupies different specifications and has miscellany of usage approaches. Therefore, a flow chart of images processing would be carried out in order to reach the best observation on a satellite image and to be able to apply different images classifications and the relevant calculations.

The main procedures applied in satellite image processing can be summarized as follows (Fig. 6):

1. Preprocessing: This step represents the preparation of satellite images, which are produced as raw data, for further processing and classification. Consequently, the available satellite images can be processed after applying the following procedures on the software:

    - Image sub-setting: It is one of the primary steps applied to define and crop the area of interest (AOI) from the entire scene of an image. This is in order reduce the size of the images and focus on the AOI, which assists in faster downloading on computing resources.
    - Atmospheric correction: This is a process done to remove any noise in the images for best purification of surface reflectance where it is done by removing atmospheric effects from satellite images.
    - Geometric correction: This correction is to reduce the noise and the sun-angle which might be resulted as images displacement due to the altitude of platform carrying the sensor. Therefore, registration is applied using "rubber sheet" transformation which warps the image on defined points.

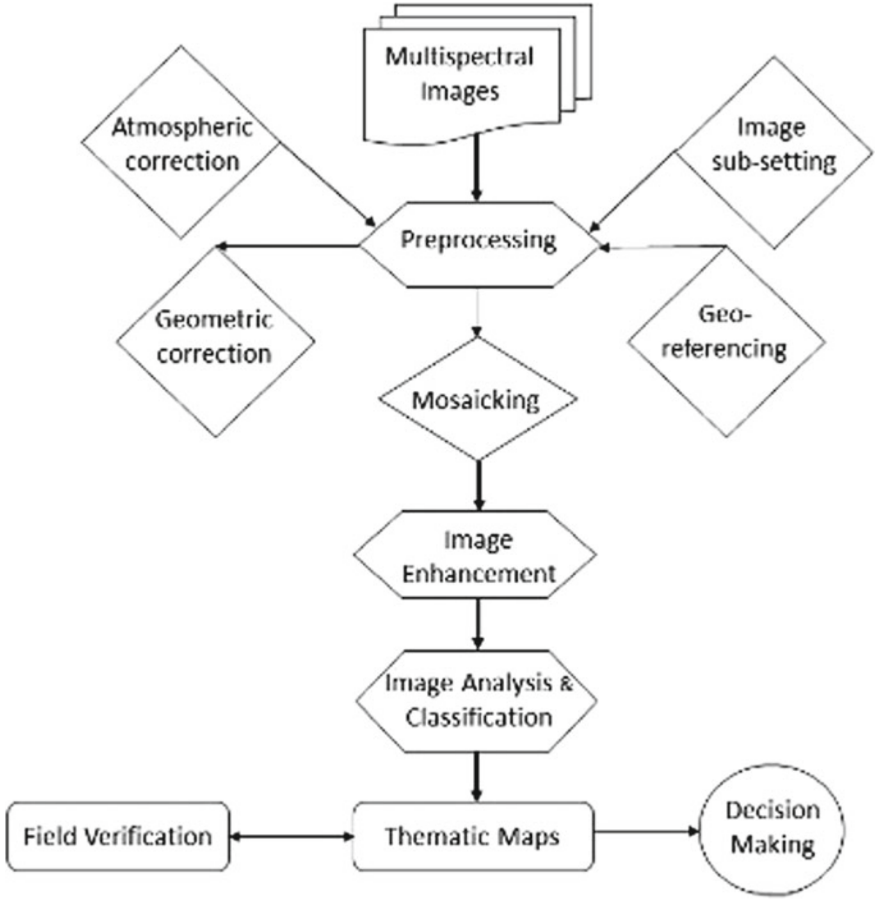

Fig. 6 Major elements of satellite images processing

- Geo-referencing: It is a necessary step for the positioning of the images with respect to the real geographic location, scale, and alignment to a file. Geo-referencing is performed on both the raster and vector data to rectify internal coordinate system with the associate objects.
- Mosaicking: This is a reversible process of image sub-setting, where multiple images from different scenes are associated together in one scene order to have a unified observation for the AOI. This is usually dependent of the purpose of the study and the surface area required.

2. Image enhancement: This is a major step applied while preparing satellite images for classification and analysis. Hence, several digital and spectral applications are applied using image processing software in order to attain the most reliable/distinguishable observation for the objects on Erath's surface. Most of

these digital applications are mostly tentative and their use is dependent on the knowledge of the images analyzer and the purpose of the study.

The most common applications of images enhancement are the: sharpness, contrasting, edge detection, color slicing, directional filtering, enhancements and interactive stretching. There is also "band combination" which is often performed for the single band and multi-band where different bands (diverse wavelengths) are arranged to reach the most suitable favorable observation.

3. Image analysis and classification: When the satellite image has been prepared according to the aforementioned pre-processing steps. Thus, the analysis and classification of a satellite image is a target process applied to recognize and discriminate the existing objects on Earth's surface, calculating their dimensions and land areas of AOI, as well as monitoring changes over time, etc.

   "Classifier", as a digital option on software, is used to group the satellite images into unified units with similar spectral signatures which also includes grouping the image pixels into categories. Image classification follows many approaches; however, the most common ones are: (1) Supervised classification where the analyzer is able to identify representative classes (i.e. training sites); and therefore, the software adopts these sites and then mainstream them to the entire image, (2) Unsupervised classification where pixels are grouped into "clusters" depending on their spectral signatures, and the each cluster can be tentatively attributed to land class, (3) Object-based classification where images pixels are grouped into representative vector shapes with define size and geometry. It is; therefore, different from supervised and unsupervised classification which are pixel-based (GIS Geography 2020).

4. Production of Thematic Maps: When the images becomes clear with defined classes and categories; therefore, the next step can be as the representation of these classes into mappable form where different colors and pattern can be illustrated to each class. Therefore, thematic maps can be produced with their legends. These produced hematic maps are usually used as base maps for filed verification to assure the reliability of the extracted data and information from the processed satellite images.

   The produced thematic maps with appropriate mapping and with readable production enabled decision makers and policy making to easily understand terrain elements and put their visions for planning based on these maps.

4 Geo-Information System

As a supplementary and significant tool for geo-spatial data extraction from satellite images, geo-information system, also called Geographic Information System (GIS) is often used. It is a computer-based system performed when the extracted geo-spatial data requires digital manipulation including digitization of the geo-spatial data, and then vector and raster data illustration of maps and layouts, storage, display all geo-spatial data as one set display, overlapping, classification and many other necessary application.

The used GIS software is almost similar to those for images processing, but the advantages of GIS technology is mainly utilized for maps production, where it integrates common database operations, such as query and statistical analysis, with maps. Therefore, different geo-spatial categories can be interlinked with attribute tables and the relevant statistics and measurements. Hence, the GIS software enables users to store and manipulate large amounts of data from remotely sensed data, GPS and other sources.

One of the main purposes for using GIS is in data modelling where different factors are integrated to elaborate a map with target results (Shaban 2020). Therefore, these factor, which represent influencers on specific theme, are then they are converted into digital thematic maps (i.e. GIS layers). Modelling of these factors is carried out by the overlapping of the thematic maps in the GIS system, where each map has a define theme, and this enables integration of different themes into a unified figure (example in Fig. 7).

Recently, the techniques of the geo-information system have been involved in the management plans at different levels, and they became a instrumentation in many institutions (e.g. authorities, research centers, universities, etc.), then these techniques became a primary tool for data management.

There are many types software types used for the manipulation of the geo-information systems. Most of the GIS software types have been developed and embedded with images processing tools. Therefore, ESRI (Environmental System Research Institute, Redlands, USA) is the major used software where it utilizes Arc-GIS, as the principal Geo-information system tool extended on ITS computers, and is installed in UNIX and Networked PC devices.

There is specified Arc-GIS terminology, the principal ones are summarized in Table 2.

The principal tools of the Arc-GIS are:

- Arc-Map which enables visualizing spatial data, performing spatial analysis and drawing maps.
- Arc-Catalog is a tool for browsing and exploring spatial data, as well as viewing a creating metadata and managing spatial data
- Arc-Toolbox is an interface for accessing the data conversion and analysis function the come from Arc-GIS.

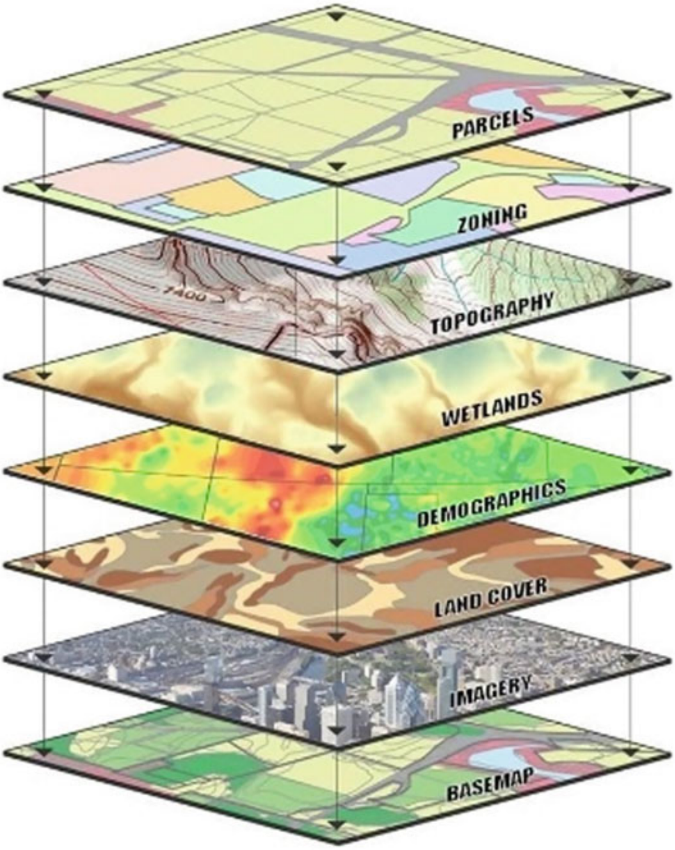

Fig. 7 GIS data layers visualization and overlaying (USGS 2016)

Table 2 Terminology of Arc-GIS (UMD 2012)

Term	Definition	Example
View	A collection of themes	Beirut
Theme	A single layer of data	Urban areas
Value	A specific quality or quantity assigned to an attribute, for a specific instance	125

References

Al Saud M (2020) Sustainable land management for NEOM region. Springer Publisher, 220 pp

American Cinematographer (2005) Bit-depth scales courtesy of Douglas Walker. https://www.theasc.com/magazine/april05/conundrum2/image11.html

Borman S, Stevenson R (1998) Super-resolution from image sequences a review. In: IEEE Midwest symposium on circuits and systems, pp 374–378

Chuvieco E (2020) Fundamentals of remote sensing, 3rd edn. CRC Press, 432 pp. https://doi.org/10.1201/9780429506482
Dixon-Gough RW (1994) Geographical information management: the way forward for remote sensing. Geodet Inf Mag 8(8):68–74
Eastman J (2001) Guide to GIS and image processing, vol l. IDRISI 32 Release 2. Clark University, 172 pp
Galbraith A, Theiler J, Kurtis T, Ziolkowski R (2005) Resolution enhancement of multilook imagery for the multispectral thermal imager. IEEE Trans Geosci Remote Sens 43(9):1964–1977
SEOS (Science Education through Earth Observation) (2021) Satellite orbits. https://www.seos-project.eu/remotesensing/remotesensing-c02-ws01-t.html
Shaban A (2020) Water resources of Lebanon. Springer Science Publisher, ISBN 978-3-030-48716-4, 229 pp
Shimizu E (2011) Satellite remote sensing. encyclopedia of life support systems (EOLSS)
Théau J (2008) Temporal resolution. In: Shekhar, Xiong (eds) Encyclopedia of GIS. https://doi.org/10.1007/978-0-387-35973-1_1376
UoB (University of Bergen) (2021) The electromagnetic spectrum. https://www.uib.no/en/hms-portalen/75292/electromagnetic-spectrum
USGS (2016) GIS data layers visulazation. https://www.usgs.gov/media/images/gis-data-layers-visualization

Water Resources in the Middle East

Amin Shaban

1 General Overview

The World's population is growing rapidly, and estimates show that with current practices, the World will face a 40% water shortfall between forecast demand and available supply by 2030. Furthermore, chronic water shortage, hydrological uncertainty, and the existing climatic extremes (e.g. floods, heat waves, etc.) are perceived as the biggest threats to global prosperity and stability (World Bank 2021).

Today, about 4 billion people (i.e. equivalent to about 2/3 of the global population) experience unlikely water shortage during at least one month of the year, and this may ascend to touch 4.8–5.7 billion in 2050 (Mekonnen and Hoekstra 2016). In this respect, any country drawing more than 25% of its renewable freshwater resources is considered as "water-stressed". Globally, 5 out of 11 regions have water stress values above 25%, including two regions with high water stress and one with extreme water stress. There is 2.3 billion people live in water-stressed countries, of which 733 million live in high and critically water-stressed regions (UN Water 2021).

The agricultural production requires about 60% increase in order to feed more than 9 billion people by 2050, and this will lead to 15% increase in water abstraction from different resources (surface water and groundwater). The increased water demand stands beside increased scarcity in water resources are scarce in many regions, and many estimates indicate that 40% of the World population live in water scarce areas, and approximately one-fourth of World's GDP is exposed to this challenge (World Bank 2021).

In the Middles East Region, water became a scarce resource with uneven distribution between different geographic regions, resulting in geo-environmental problems on the national level and geo-political conflicts between riparian countries on the

A. Shaban (✉)
National Council for Scientific Research—Lebanon (CNRS-L), CNRS-L, P.O. Box 11-8281, Beirut, Lebanon
e-mail: geoamin@gmail.com

A. Shaban (ed.), *Satellite Monitoring of Water Resources in the Middle East*,
Springer Water, https://doi.org/10.1007/978-3-031-15549-9_2

regional level. Today, the sixteen countries in this region are placing unprecedented stress on water supply led to an abrupt increase in water demand, threatening food security and the entire ecosystem. The largest part of the Middle East Region is located within arid and semiarid regions where precipitation is lower than 200 mm and evapotranspiration exceeds 55%. Thus, it is a typical example where water resources are inadequate to cope with human demand for all major sectors.

There are 13 Arab countries within the Middle East Region (Fig. 1), comprising 62% (285.19 million people) of the total population and 66.5% (4,848,674 km^2) in surface area.

The Arab Region is mainly an arid or semi-arid, receiving less than 250 mm of rainfall annually beside a rapid increase in population. Hence, water shortage is widespread and it threatens people and livelihoods, particularly in rural and poor communities, but it also affects urban dwellers in the developing countries. It has been reported from the current projections that by 2025 the water supply in the Arab Region will be only 15% of what it was in 1960 (UNDP 2013). According to FAO (2013), 12 Arab countries have water availability below the World Health Organization threshold for severe scarcity (1000 m^3/capita/year).

Fig. 1 Location maps for the Middle East countries (Alamy 2022)

Likewise, many regions worldwide, the freshwater scarcity in the Middle East is influenced by several factors, including mainly rapid population growth, climate change impacts and extreme climatic events, dependency on transboundary water resources, water pollution, non-revenue water losses from ageing water systems, intermittency in the discharge, inefficient water use.

The surface area and population of the Middle East countries are shown in Table 1. It is clears that the largest area is for the Kingdom of Saudi Arabia (2.15 million km^2), besides the smallest one for Palestine (6020 km^2), while the biggest population is in Egypt (104.26 million people) and the least one is in Cyprus (1.21 million people).

Table 1 also shows that the average surface area is about 455,530 km^2, whereas the average population was estimated at 28.5 million people. Moreover, the density population density in the Middle East Region is extremely diverse and it ranges between 16 and 2285 person per km^2.

Table 1 Area and population of the Middle East in 2021 (UN 2021)

Country	Surface area (km^2)	Population (million people)	Population density (person/km^2)
Bahrain	766	1.75	2285
Cyprus	9251	1.21	132
Egypt	1,002,000	104.26	104
Iran	1,647,000	85.02	52
Iraq	438,317	41.17	94
Jordan	89,342	10.27	115
Kuwait	17,818	4.32	243
Lebanon	10,452	6.76	647
Oman	309,500	5.22	17
Palestine	22,145	14.4	840
Qatar	11,586	2.95	253
Saudi Arabia	2,150,000	35.34	16
Syria	185,180	18.27	99
Turkey	783,562	85.04	109
UAE	83,600	9.99	120
Yemen	527,968	30.49	58
Total	7,288,487	456.46	–
Average	455,530	28.53	324

2 Water Availability/Supply and Demand

Water availability is the biophysical supply of water resources with respect to the demand and access to water. It can be assessed from the diagnose of the water cycle starting from precipitating and becoming available as surface water and groundwater. In other words, the availability of water is the amount of renewable water which is naturally available in an area with respect to the population size in this area, and it is often calculated by m^3/capita/year. Thus, water availability is controlled by the total water volume (i.e. resource) and the population size (i.e. consumers).

Water supply is well known as the volume of water that delivered for different consumers, and this is often implemented by the formal sector (e.g. water authorities, ministries, etc.). Besides, water demand is the water volume required for consumers (for all uses) in order to cope with their requirements for sustainable life.

In this regard, the internationally water-poverty threshold is 1000 m^3/capita/year and this characterizes all arid and semiarid regions where water is naturally scarce. However, calculating water availability often results imprecise figures, especially in relatively vast areas with major water resources (e.g. major rivers), and then these resources can supply water only the nearby areas while remote ones remain scarce.

For example, there are Nile River in Egypt, and Tigris and Euphrates Rivers in Iraq which span for long distances, but almost over dry areas and deserts. Hence, water is available only in the surrounding of these rivers, but this is not the case for the remote areas in these countries. Therefore, the general calculations for water availability in these regions is high, while water scarcity exists in many parts in these countries at the same time. Therefore, water availability does not reflect acceptable water supply.

Except Cyprus, Lebanon, NW part of Syria, Turkey and Iran, the rest Middle East countries are known by low precipitation and frequent drought spells. These five regions are located above 33° latitudes and they are also characterized by elevated topography. Figure 2 shows examples from two diverse regions from the Middle East reflecting water availability.

The Middle East countries occupy a number of large-scale water resources (i.e. rivers and aquifers). However, these resources are shared between the riparian countries even outside the Middle East Region, and then result in geo-political conflicts. Besides, there is an obvious drop in the renewable water resources estimated by 50% over the last few decades (UNESCO 2017). Table 2 shows the list of water availability, supply and demand and the ratio between them for the Middle East countries.

It is obvious that the average renewable water (water availability) in the Middle East Region is about 631m^3/capita/year which can be considered as low to moderate if compared with the global figure on water availability.

Out of the 16 Middle East countries, there are 13 already considered as water-scarce countries (i.e. below water poverty threshold, of 1000 m^3/capita/year), where 9 of them are under 500 m^3/capita/year, and 7 of the latter are even under 100 m^3/capita/year. Based on the existing climatic conditions and the urban development,