Springer Water

Ayad M. Fadhil Al-Quraishi
Abdelazim M. Negm *Editors*

Environmental Remote Sensing and GIS in Iraq

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.

More information about this series at http://www.springer.com/series/13419

Ayad M. Fadhil Al-Quraishi ·
Abdelazim M. Negm
Editors

Environmental Remote Sensing and GIS in Iraq

Springer

Editors
Ayad M. Fadhil Al-Quraishi
College of Engineering
Knowledge University
Erbil, Kurdistan Region, Iraq

Abdelazim M. Negm
Faculty of Engineering
Zagazig University
Zagazig, Egypt

ISSN 2364-6934 ISSN 2364-8198 (electronic)
Springer Water
ISBN 978-3-030-21343-5 ISBN 978-3-030-21344-2 (eBook)
https://doi.org/10.1007/978-3-030-21344-2

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

Preface

This volume came into conception to highlight the use of remote sensing (RS) and geographic information system (GIS) and their applications in Iraq. This unique volume is authored by experts in the topic from Iraq and other countries too to present the results and findings of their research work and the related state of the art connected to the book title. The volume consists of five parts excluding the introduction and the conclusions parts. The book is comprised of 21 chapters written by more than 40 authors. **Part I** is an introduction to the environmental remote sensing and GIS in Iraq, where the editors present a general overview and highlight the technical elements of each chapter.

Part II of the volume is titled "**Soil Characterization, Modelling, and Mapping**" and contains three Chaps. 2, 3, and 4. Chapter 2 is titled "**Using Radar and Optical Data for Soil Salinity Modeling and Mapping in Central Iraq**". The chapter is aiming to ascertain the possibility to propose a simple and operational approach for soil salinity assessment by combining both radar and optical data as a complement to the available optical ones. The specific objectives were (1) to develop combined soil salinity model(s) by incorporating radar backscatter coefficient with biophysical indicators from optical data, and (2) to explore the potential to develop a radar-based model(s) for the same purpose. While Chap. 3 is titled "**Using Remote Sensing to Predict Soil Properties in Iraq**" and is devoted to demonstrating the development of some statistical models to predict some components of Iraqi soils using remote sensing techniques including spectral indices and electromagnet induction. The last chapter in Part II is titled "**Characterization and Classification of Soil Map Units by Using Remote Sensing and GIS in Bahar Al-Najaf, Iraq**". The chapter aims to find out the possibility of using remote sensing (RS) and geographic information system (GIS) techniques in contributing to soil surveys by selecting soil map units drawing and calculating spectral reflectance by satellite image of Landsat 8 provided with two sensors: Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS).

On the other hand, **Part III** is titled "**Proximal Soil Sensing**" and contains two Chaps. 5 and 6. Chapter 5 entitled "**Proximal Soil Sensing for Soil Monitoring**". The chapter brings together ideas and examples from developing and using proximal soil sensing (PSS) and proximal sensors for applications, such as precision agriculture and soil contamination monitoring with specific attention to Iraq soils. While Chap. 6 titled "**Proximal Soil Sensing Applications in Soil Fertility**" is presented to show how to predict soil total nitrogen (N) and available phosphor (P) by using Vis-NIR Spectroscopy technique. This is essential to help in fertilization management to avoid under- or over-fertilization, to reduce agricultural input costs, and to provide sustainability strategy.

Part IV is titled " **RS and GIS for Land Cover/Land Use Change Monitoring**" written in three Chaps. 7, 8, and 9. In Chap. 7 with the title "**Multi-temporal Satellite Data for Land Use/Cover (LULC) Change Detection in Zakho, Kurdistan Region-Iraq**," the author aims to provide information on LULC using multi-temporal Landsat images in Zakho district, Duhok, Kurdistan region, Iraq, for which detailed thematic maps are currently lacking. In the chapter, three main tasks are identified and achieved including: (a) identifying and defining types of LULC for the study area, (b) examining the variation in the distribution of LULC, and (c) providing an up-to-date database and produce accurate maps. While the authors of Chap. 8 under the title "**Monitoring of the Land Cover Changes in Iraq**" aim to evaluate the nature, and rate of climate and vegetation change from 2002 to 2016 using Tropical Rainfall Measuring Mission (TRMM) and Moderate Resolution Imaging Spectroradiometer-Normalized Difference Vegetation Index (MODIS-NDVI) time series by considering the variations in April. Moreover, the chapter deals with finding a statistical relationship between the density of vegetation and elevation in Iraq territory. Also, the authors monitored the change of some climate variables such us precipitation and temperature of Iraq using multi-in-situ and satellite data. Additionally, Chap. 9 entitled "**Effects of Land Cover Change on Surface Runoff Using GIS and Remote Sensing: A Case Study Duhok Sub-basin**" endeavors to examine the impact of the urban landscape pattern changes at a local level on the volume of runoff, which depends on a satellite image time series from 1990 to 2016 and using the city of Duhok, Kurdistan region, Iraq as a case study.

Part V has the theme "**Land Degradation, Drought, and Dust Storms**" and is covered in six chapters from 10 to 15. In Chap. 10 titled "**Monitoring and Mapping of Land Threats in Iraq Using Remote Sensing**," the author tries to demonstrate the output for some works, which have been done on monitoring and mapping spatial and temporal changes of Iraqi resources using remote sensing and GIS techniques. While in Chap. 11 under the title "**Agricultural Drought Monitoring Over Iraq Utilizing MODIS Products**," the authors use the remote sensing techniques for mapping agricultural drought maps from 2003 to 2015 in Iraq. They indicated that most of Iraqi agricultural lands are highly affected by one or more of the desertification processes due to poor management practices, dry climatic conditions, and effects of socio-economic factors.

On the other hand, Chap. 12 is titled "**The Aeolian Sand Dunes in Iraq: A New Insight**" and is devoted to detecting the aeolian sand dunes' changes between 2000 and 2016 using Landsat imagery for entire Iraq. Moreover, the authors determine the activity of the aeolian sand dunes' movement in an area in the central part of the

Mesopotamia by applying DInSAR technique for the period between March 2015 and August 2016 using Sentinel 1A. While Chap. 13 under the title "**Drought Monitoring for Northern Part of Iraq Using Temporal NDVI and Rainfall Indices**" combines both meteorological and remote-sensed indices to map drought conditions in the northern part of Iraq. The authors show that desertification has been increased in the study area. The authors aim to use the NDVI and SPI indices to detect the appearance and severity of the drought event for the northern part of Iraq.

Moreover, Chap. 14 is written under the title "**Remote Sensing and GIS for Dust Storm Studies in Iraq**" to demonstrate the spatial–temporal distributions of sources, causes, and atmospheric and wind patterns of dust storms as well as their environmental circumstances (air–soil–vegetation–water) in Iraq. Additionally, Chap. 15 is titled "**Drought Monitoring Using Spectral and Meteorological Based Indices Combination: A Case Study in Sulaimaniyah, Kurdistan Region of Iraq**". The authors attempt to highlight the benefits of the combination of the spectral and meteorological based indices for drought monitoring and mapping in Sulaimaniyah, Kurdistan region, Iraq.

Part VI contains five chapters, from 16 to 20 chapters. They are presented under the theme "**RS and GIS for Natural Resources**." Chapter 16 is titled "**Geo-Morphometric Analysis and Flood Simulation of the Tigris River Due to a Predicted Failure of the Mosul Dam, Mosul, Iraq**". The chapter covers two main objectives: (a) performing geo-morphometric analysis for a specific river basin in the northern part of Iraq that includes Mosul Dam, and (b) delineating flooded zone due to a predicted collapse of the Mosul Dam. While Chap. 17 under the title "**Hydrologic and Hydraulic Modelling of the Greater Zab River-Basin for an Effective Management of Water Resources in the Kurdistan Region of Iraq Using DEM and Raster Images**" presents the computational design of the hydrologic and hydraulic modeling system for the Greater Zab River Basin in the Kurdistan region of Iraq.

On the other hand, Chap. 18 titled "**Spatial Assessment of Drought Conditions Over Iraq Using the Standardized Precipitation Index (SPI) and GIS Techniques**". The chapter aimed to assessing, monitoring, and mapping of long-term drought and wet condition by using Standardized Precipitation Index (SPI), which is the best way to put efficient water policy and management in Iraq.

Additionally, Chap. 19 is presented under the title "**Assessing the Impacts of Climate Change on Natural Resources in Erbil Area, the Iraqi Kurdistan Using Geo-Information and Landsat Data**". It aims to quantitatively study the large-scale semi-aridization of the climate in the Kurdistan region of Iraq, revealed by the rise of temperatures and the decline of the amount of precipitations, and aims to quantify spatial and temporal dynamics of LULC, in particular, the changes in vegetation, surface water and urban and built-up areas in the study area. The last chapter in this part is titled "**Mapping Forest-Fire Potentiality Using Remote Sensing and GIS, Case Study: Kurdistan Region-Iraq**." It is aiming to map the areas of most potential of firing to help the managers to follow preventive actions because a great number of forest fires have been recorded in the north of Iraq where it is almost the only area in Iraq forests are remaining.

The last chapter in this book (**Part VII**) is the conclusions and recommendations and is written by the editors. The chapter presents an update of the most recent findings, the most significant conclusions, and recommendations of the chapters contained in the volume.

Special thanks are due to all authors who contributed to this volume; without their efforts and patience, it would not have been possible to produce this unique volume on Environmental RS and GIS in Iraq. Also, thanks should be extended to include the Springer team who largely supported the authors and editors during the production of this volume.

Zagazig, Egypt — Abdelazim M. Negm
Erbil, Kurdistan Region, Iraq — Ayad M. Fadhil Al-Quraishi
April 2019

Contents

Part I
Introduction

Chapter 1
Introduction to "Environmental Remote Sensing and GIS in Iraq"

Ayad M. Fadhil Al-Quraishi and Abdelazim M. Negm

Abstract This chapter presents the main technical features of the book titled "Environmental Remote Sensing and GIS in Iraq". The book consisted of seven parts including the introduction (this chapter) and the conclusions (the closing chapter). The main body of the book consisted of five themes to cover Soil Characterization, Modelling, and Mapping in three chapters, Proximal Soil Sensing in two chapters, remote sensing (RS) and Geographical Information Systems (GIS) for Land Cover/Land Use Change Monitoring in three chapters, Land Degradation, Drought, and Dust Storms in six chapters, and RS and GIS for Natural Resources. The main technical elements of each chapter are presented under its relevant theme.

Keywords Remote sensing · GIS · Land degradation · Soil · Modeling · Mapping · Drought · Proximal · Natural resources · Iraq

1.1 Iraq: A Brief Background

Iraq, officially the Republic of Iraq (Fig. 1.1), is a country in Western Asia, bordered by Turkey to the north, Iran to the east, Kuwait to the southeast, Saudi Arabia to the south, Jordan to the southwest and Syria to the west. Iraq is located between latitudes 29° 5′–37° 22′N and longitudes 38° 45′–48° 45′E, with a total area of 438,317 km^2. Its capital is Baghdad, which is the largest city in the country.

A. M. F. Al-Quraishi
Environmental Engineering Department, College of Engineering, Knowledge University, Erbil 44001, Kurdistan Region, Iraq
e-mail: ayad.alquraishi@gmail.com; ayad.alquraishi@knowledge.edu.krd

A. M. Negm (✉)
Water and Water Structures Engineering Department, Faculty of Engineering, Zagazig University, Zagazig 44519, Egypt
e-mail: amnegm@zu.edu.eg

A. M. F. Al-Quraishi and A. M. Negm (eds.),
Environmental Remote Sensing and GIS in Iraq, Springer Water,
https://doi.org/10.1007/978-3-030-21344-2_1

Fig. 1.1 The map of Iraq. *Source* Iraq, Map No. 3835 Rev. 6. July 2014. Courtesy of the United Nations, http://www.un.org/Depts/Cartographic/map/profile/iraq.pdf

During the ancient times, the lands that now constitute Iraq were known as *Mesopotamia*, which means "(Land Between the Rivers), a region whose extensive alluvial plains gave rise to some of the world's earliest civilizations, including those of Sumer, Akkad, Babylon, and Assyria. This wealthy region, comprising much of what is called the *Fertile Crescent*. Later became a valuable part of larger imperial polities, including sundry Persian, Greek, and Roman dynasties. Moreover after the 7th century, it became a central and integral part of the Islamic world. Iraq's capital, Baghdad, became the capital of the Abbāsid caliphate in the 8th century. The modern nation-state of Iraq was created following World War I (1914–18)" (https://www.britannica.com/place/Iraq).

Around 97% of the country is in arid lands with low and erratic rainfall. In most parts agriculture suffers from high rates of evapotranspiration that exceed rainfall. Temperature varies widely (10–40 °C) during the growing season, particularly in desert regions. Iraq is an agricultural country. Although a considerable portion of its agricultural lands is under irrigation, it still depends highly on the rainfed agriculture for grain and sheep production (http://www.fao.org/iraq/fao-in-iraq/iraq-at-a-glance/en/). "Rainfed agriculture is practiced in the northern parts where the mountains, foothills, and Jazeera desert are located" (https://documents.wfp.org/stellent/groups/public/documents/ena/wfp291289.pdf). These three regions depend mostly on rainfall for agricultural production and supply a substantial part of the grain (wheat and barley) consumed in the country. Of the 120,000 km^2 of cultivable land, which comprise 26.4% of the total area, there are 40,000 km^2 in the rainfed region.

The next section will present the technical aspects of the chapters under their related themes.

1.2 Soil Characterization, Modelling, and Mapping

This theme is covered in three chapters. Chapter 2 titled "Using Radar and Optical Data for Soil Salinity Modeling and Mapping in Central Iraq". In this chapter, Landsat 5 TM imagery and ALOS (Advanced Land Observing Satellite) L-band SAR data acquired at almost the same time were used for this study. Water Cloud Model (WCM) proposed by Attema and Ulaby (1978) was applied to minimize the impacts of vegetation cover and moisture on the soil components of the backscattering coefficients. After this processing, the soil components have gained an increase in correlation coefficients with the measured apparent soil salinity (ECa) by 7.5–25.6%.

A radar-optical combined dataset including all the biophysical indicators from Landsat TM images, L-band backscattering coefficients, and its soil components were produced. A multivariate linear regression (MLR) modeling was applied to couple the optical and radar indicators with the apparent soil salinity and to establish the combined and radar-based soil salinity models. Results revealed that the optical-radar combined or radar-based models can reliably predict soil salinity with an accuracy of 74.0–84.3% ($R^2 = 0.739$–0.843).

To sum up, removal of vegetation cover impacts can greatly improve the salinity prediction accuracy and reliability by radar data, but radar-optical combined dataset can deliver better soil salinity prediction and mapping results. Radar data have great potential for soil salinity mapping. Development of a radar-based approach for minimization of vegetation cover impacts on the backscattering coefficients without any dependence on the optical data is recommended in future work.

While Chap. 3 is focusing on "the use of Remote Sensing to Predict Soil Properties in Iraq". Therefore, the main objectives of this chapter are to demonstrate the development of some statistical models to predict some components of Iraqi soils using remote sensing techniques. The soil is one of the most important components of agricultural production and can have a dominant effect on crop yields and quality. "Different methodologies have been proposed for the estimation of soil parameters, based on different remote sensing sensors and techniques" (https://www.hindawi.com/journals/aess/2011/904561/). In-field soil information has been used for centuries by farmers to make decisions concerning crop management practices. Quantitative information and spatial distribution of soil properties are among the main prerequisites for achieving sustainable land management. The accuracy of soil information determines, to a large extent, the reliability of land resources management decisions. The results indicated that the remote sensing techniques are a very useful tool to predict soil organic matter (SOM), total Nitrogen, salinity level and some physical soil properties including the content of clay, silt, sand, and infiltration rate. The results revealed a highly significant relationship between the measured values for the selected soil properties and the predicted values. Finally, we can sum up that remote sensing multi-temporal satellite data has proven to be an important tool to predict some physical and chemical soil properties on a large scale using different indices, including NDVI, SAVI, and GDVI. Remote sensing techniques are very accurate, useful and helpful to predict the properties of the surface soil as they can consume efforts, time and money.

Moreover, Chap. 4 is dealing with the characterization and classification of soil map units by using remote sensing and GIS in Bahar Al-Najaf, Iraq. The chapter aims to find out the possibility of using remote sensing (RS) and GIS techniques to show the nature and interference effect of the relationship between some of the soil physical and chemical properties on its spectral reflectance values by choosing false-color composite RGB (753) and subsetting study area using ERDAS imagine 2013. Depending on the unsupervised classification, as well as soil indicators such as soil color, texture, natural plants and topography in determining the researcher movement paths to select 16 Pedons with 21 auger hole sites for surveying and isolating expected soil individuals which are identified using US modern classification. All the studied soils are within the Entisol order, which classified into two of Suborders. The first is Fluvents including great soil group Torri fluvents and subgroup Typic Torri fluvents, which includes 9 Soil series ME1, DW56, TW964, DM44, MW3, TE354, DW124, DE47, DE126. The second is Psamments including two great soil groups, The first Torri psamments containing subgroup Typic Torri psamments including DE33, DE34, DE74, TE334, TW446 soils series. The other quartzi psamments include subgroup Typic quartzi psamments containing two soil series ME1, DM14. The soil series are classified according to the proposed (Al-Agidi 1976) for alluvial Iraqi soils classification.

1.3 Proximal Soil Sensing

This theme is covered in two chapters. Chapter 5 is devoted to soil monitoring using proximal soil sensing technique. In a quest to derive information on potentials and limitations of soils and to increase the efficiency of soil survey and to make it cost-effective, PSS and soil spectroscopy have been used, and a perceptible improvement in the level of information that could be derived has been achieved. Finding suitable data preprocessing and calibration strategies for the application of Visible-Near Infrared-Short Wave Infrared (VIS-NIR-SWIR) spectroscopy is dramatically significant and influence the final accuracy. Moreover, inaccuracy and uncertainties occur at the different steps in the prediction procedure, and the accuracy of the resulting models can be insufficient for the planned purpose; therefore, it is important to assess the accuracy of the process. The chapter also provided a short study as a case study on employing soil spectroscopy in Sulaimani, Iraqi Kurdistan Region. The spectroscopy technique was used for monitoring and mapping total Fe, and Fe_2O_3 rich soils of some sites in the area. The statistical accuracy and distribution maps obtained using laboratory spectroscopy measurements indicated that, for the soil Fe and Fe_2O_3 under study, laboratory proximal level prediction could give a reasonable indicator based on spectra from soil samples. According to the study, the accuracy and distribution maps derived from laboratory spectroscopy measurements proved the capability of laboratory proximal level prediction for assessing the soil Fe and Fe_2O_3 under study area in Sulaimani, the Iraqi Kurdistan region.

Chapter 6 is dealing with the application of proximal soil sensing to monitor soil fertility. The chapter outlines a historical review of Proximal sensing along with its applications as a potential analytical technique for studying in different fields of study. To this end, the chapter contains background about the use of VIS-NIR-Spectroscopy in soil analysis such as soil minerals, texture, organic matter, water content and fertility with focusing on nutrients (N. P. and K.). The methodological part of this chapter overviews the sampling and preparation of soil for studying steps. The second section of the methodological part describes VIS-NIR Spectra analysis, calibration, spatial variability of total N, available P using GIS-Kriking Analysis and ended with the evaluation of prediction power. The chapter will finish with the discussion of the findings of this study.

The obtained prediction model quality parameter values were at best successfully model to predict soil total N and available P and well suited for a large variety of low to high concentrations under the condition of this study.

Finally, chapter puts its recommendations to pay attention toward strategic of the Iraqi Soil Spectral Library at the country to directly be used in soil monitoring and fertilization management.

1.4 RS and GIS for Land Cover/Land Use Change Monitoring

This theme is covered in Chaps. 7, 8 and 9. Chapter 7 is directed to use the multi-temporal satellite data for land use/cover (LULC) change detection in Zakho, Kurdistan region-Iraq. Land use/cover (LULC) affects local, global environment, climate and land degradation that reduces ecosystem services and functions. Monitoring of LULC is important to assess the change and manage the environment. Remote sensing is one of the effective techniques that plays an active role in accomplishing such tasks. Landsat data is widely used for change detection of LULC and mapping earth surface. Also, Landsat images used to map and extract several objects on the earth surface. The chapter aims to provide information on LULC using multi-temporal Landsat images in Zakho district, Duhok, Kurdistan region, Iraq for a period of 28 years (1989–2017). Such a task was performed by (1) identify and define types of LULC for the study area, (2) examining the variation in the distribution of LULC, and (3) provide an up-to-date database and produce accurate maps.

The authors indicated that the overall pattern of LULC change in the Zakho district over the past 28 years was one of the sprawl of crops and built-up lands. Adding to that, a substantial reduction of forest and grassland indicates an acceleration stage of agriculture and urbanization. Despite the pressing land requirements for urbanization, land development and consolidation in grass and forest areas, and the adjustment of the agricultural structure, the foundation was put for the transition to intensively use the land in the Zakho district. It is recommended to reduce urban expansion in agricultural areas, especially in the Sindi plain, moreover, to work on the vertical expansion of residential areas to accommodate population increment.

In Chap. 8, the authors used the RS to monitoring land cover changes in Iraq. The chapter describes the use of Moderate Resolution Imaging Spectroradiometer (MODIS) land cover maps—covering the period 2003 to 2013—for monitoring changes in the vegetation cover. They studied key factors controlling the spatial distribution of vegetation cover and types of vegetation and found a strong correlation between the NDVI values (using MODIS-NDVI scenes) and DEM within the Iraqi territory. There are 17 classes of land cover in Iraq, five of them are classified as non-vegetative, which include barren or sparsely vegetated; permanent wetlands; snow and ice; urban and built-up areas; and water. The rest are vegetation classes, which are closed shrublands, open shrublands, cropland/natural vegetation mosaic, croplands, deciduous broadleaf forest, deciduous needleleaf forest, evergreen broadleaf forest, evergreen needleleaf forest, mixed forest, grasslands, savannas, and woody savannas. Dominant vegetation classes in Iraq are shrublands (58.52%), croplands (27.29%) and grasslands (13.69%), which are located in Mesopotamia and the northern part. The western and southwestern parts of Iraq are mostly desert. The average area of shrublands, croplands, and grasslands estimated for the period, 2003–2013 was 66, 122, 30, 832, and 15,472 km^2, respectively.

The relationship between the digital elevation model and the NDVI values of the grasslands in Iraq shows good inverse correlation, where R^2 values were found to be greater than 0.7. There is no vegetation (NDVI value more than 0.2) above 2,600 m elevation. Moreover, no statistical relationships could be obtained between elevation and croplands or the shrublands. This is because croplands and shrublands are found at various elevations (i.e., lowlands and mountainous lands). On the contrary, grasslands occur in both the foothills and mountainous lands. The authors concluded that one of the major causes of eco-environmental degradation in Iraq is ineffective and wasteful utilization of land cover, particularly the vegetation cover that, to a large extent, contributes to climate change. Four main factors have resulted in the development of modern land cover in Iraq; these are climate, surface and subsurface water, lithology, and relief. Hence, a strong correlation was found between these factors, and the spatial distribution of the land cover classes is strong. It is important to reduce soil salinity and control sabkha development by preventing the use of Al-Tharthar Lake water for irrigation as it contributes to washing out of salts that ultimately enters the Euphrates River.

Moreover, Chap. 9 focus on the effects of land cover change on surface runoff using GIS and remote sensing with application to Duhok Sub-Basin, Kurdistan region, Iraq as a case study.

To quantify the impact of land cover changes on runoff, a simple hydrological model directly considering land use/land cover is used. The Soil Conservation Service Curve Number (SCS-CN) was used to assess surface water volume for a given rainfall event for the small watershed area. The integration of a GIS and remote sensing was used and “is recognized as a useful and effective tool in locating urban” growth (https://www.mdpi.com/2306-5338/4/1/12/pdf). The main objective of this study focuses on pattern changes of land cover due to urbanization in the Duhok sub-basin, Kurdistan region of Iraq, as well as their effect on rainfall surface runoff. The data used in this study were multispectral satellite imaginaries. Multitemporal and multispectral satellite images were used to generate historical land use/land cover and digital land use maps were generated to estimate the effect of land cover changes on the hydrologic evaluation. The ArcGIS and Idrisi were used to determine the spatial distribution of rainfall and land cover changes. Rainfall Grids were calculated and mapped for a selected rainfall depth per pixel. Inverse Distance Weighting (IDW) interpolation method was used to estimate the rainfall spatial distribution. The methodology used for assessing the spatio-temporal variations of runoff depth for all pixels of the study area using the Soil Conservation Service Curve Number model. To sump up, Duhok sub-basin was subjected to significant land use changes in the period from 1990 to 2016. The study indicates that the urban growth of the watershed increased from 10% in 1990 to 70% in 2016. Surface runoff volume increased from 12% in 1990 to 36% in 2016, while the vegetation land decreased from 47 to 14% in the same period.

1.5 Land Degradation, Drought, and Dust Storms

This theme is covered in six chapters from Chaps. 10 to 15. Chapter 10 is devoted to explaining the use of RS in monitoring and mapping of land threats in Iraq. There is a great need to monitor the natural resources and their properties in practical place and time. Remote sensing and GIS techniques are very useful for monitoring and mapping the main type of Iraq land degradation processes as reflected by high salt accumulation and sand dunes movements. More than 25% of the land area of Iraq has a serious erosion problem, while larger than 20% of the total area, mainly in southern Iraq was seriously affected by water lodging and more than 70% was affected by salinization. Lack of comprehensive information about national land resources increases the risk of releasing uninformed policy decisions, avoidable continued degradation of land, water resources and land cover. Remote sensing offers a unique opportunity in monitoring, assessing and empirically quantifying spatial and temporal changes in soil and vegetation taking place during a long period. The objective of this chapter is to demonstrate the important of using remote sensing and GIS techniques for monitoring and mapping spatial and temporal changes of Iraqi resources. The results for the application of remote sensing indicated that the main degradation processes are affecting the Iraq agricultural lands represented by salinity and sand dunes movement. More than 70% of agricultural lands are suffering from salt accumulation as reflected by the domination of bare land in Iraq.

While Chap. 11 is dealing with agricultural drought monitoring over Iraq utilizing MODIS. Remote sensing dataset and techniques were employed in this chapter. Four different spectral indices; Vegetation Health Index (VHI), Vegetation Drought Index (VDI), Visible and Shortwave infrared Drought Index (VSDI), Temperature–Vegetation Dryness Index (TVDI) were utilized, each of them is derived from the MODIS dataset of Terra satellite. The results revealed the year 2008 was the most severe drought year the period from 2003 to 2015 in Iraq, whereas the drought covered 37% of the vegetated lands, while 2009, 2011, and 2012 were the less-severe drought years dominated by mild or moderate drought with an areal coverage of 44, 50, and 48.5%, respectively. The Vegetation Drought Index (VDI) was found to be the more suitable drought index, which can be used for Iraq, because of the temperature integration in its structure in addition to meeting the assumptions it was based on.

In Chap. 12, authors present a new insight for the aeolian sand dunes in Iraq. As a matter of the fact that there are three major accumulations of aeolian sands existing in Iraq. The first accumulation occurs as a long strip along the Abu Jeer Fault Zone, where huge fields of sand dunes extend to near the Euphrates River, from north of Karbala to south of Al-Muthanna governorates. The second major accumulation is located in the foothills of Hemreen and Mak'hool mountains. These two dunes fields are relatively older and have existed for over 20 years. The third is a recent accumulation that occurs in the middle of the Mesopotamian Plain, lying between the two old accumulations. The last one includes three large dunes fields located to the east of

Baghdad, south of Al-Qadissiya, and south of Thi-Qar governorates. All three accumulations trend in a NW-SE direction. The three sand accumulations in Iraq include almost all of the aeolian sand dunes—i.e., sand accumulation related to topographic obstacles; sand accumulation related to vegetation; sand accumulation related to bed roughness; and those formed due to aerodynamic fluctuations. The accumulations range in length from 1 m to several 10’s of km, and from few centimetres to about 150 m in height.

Arid to semi-arid climatic conditions, difficulty of access and high costs of ground surveys make it extremely difficult and expensive to study the migration patterns of the huge sand accumulations. Use of multitemporal remote sensing techniques offers an attractive and cost-effective option for mapping the desertification processes as it reduces the time and cost. Accordingly, Landsat data was utilized for spectral analyses to monitor spatiotemporal changes and activity of dunes, supported by ground check to determine the extent of aeolian sand accumulations. Results show that areas of sand dunes in Iraq have increased during the period 2000–2016 to about 4,528 km^2, as compared to about 9,891 km^2 in 2000, and about 14,419 km^2 in 2016. Additionally, the study applied DInSAR technique using Sentinel 1A data to a specific site in the central part of the Mesopotamian Plain (Hor Al-Dalmaj) to estimate the dunes displacement. Vertical displacement was found to range between ~33 and ~−40 cm and the volume of the sand dune ~5.9 times smaller than the volume of eroded sand dunes.

The authors conclude that the aeolian sediments in Iraq represent an active system whose on-going migration results in loss of agricultural land, highway obstruction, etc. Moreover, the desertification is increased in the Mesopotamian Plain for recent decades.

On the other hand, Chap. 13 investigate the drought monitoring for the Northern part of Iraq using temporal NDVI and rainfall indices. Therefore, the chapter contains background about: drought as a concept, drought impacts on soil properties, drought monitoring, remote sensing and GIS (how are they used in drought studies). In order to describe and quantify this disaster from different perspectives: meteorological, hydrological and agricultural, the chapter begins with a review of drought as a concept and definition. Drought phenomenon classified as a hazard natural disaster that depreciates the sustainable development of society. Due to its crawling nature, its effects may take weeks or months to appear in a reduction of surface/ground water to support crop growth and human activities. The severity of drought is often associated not only with the deficiency of precipitation, but also with other climatic factors such as high temperature, high wind, and low humidity. After giving this overview, the chapter will shift to the empirical part through analyzing the standardized precipitation index (SPI), which is used to classify the drought events according to meteorological data. To study the main features of intense drought events impacts on the vegetation cover, the Normalized Difference Vegetation Index (NDVI) has calculated as a most commonly used index to classify the drought severity based on NDVI anomalies. The chapter will finish with the discussion of the findings of this study.

Moreover, Chap. 14 explains the use of remote sensing and GIS for dust storm studies in Iraq to summarize the main characteristics of dust storms in Iraq. The method is based on the synthesis of RS and GIS knowledge and information to assess the situation of dust storms in Iraq. The author have mentioned some examples of case studies and projects in Iraq. Remote sensing for dust storm studies including dust sources mapping, detection of dust events using satellite imagery, wind speed, and direction, the trajectory of suspended dust particles, soil data and land surface coverage map/information. In addition to atmospheric patterns of dust storms dust sources modeling with GIS, knowledge-based approaches for dust studies with GIS, fuzzy inference systems, expert systems. The use of GIS for improving the monitoring and early warning system and spatiotemporal modeling of epidemic diseases are also presented. It is worth mentioning that dust storm studies require a comprehensive framework for implementing remote sensing and GIS in combination with other disciplines of the sciences and technologies.

Also, Chap. 15 is about drought monitoring using a combination of spectral and meteorological indices with a focus on Sulaimaniyah, Kurdistan region, Iraq as a case study. The drought has dramatically affected Iraq including the Kurdistan region throughout the last decades, which were characterized by a large drop in rainfall, and its main rivers discharge in general. This chapter aimed to investigate the role of the integration of NDVI and SPI for drought monitoring in the Kurdistan region of Iraq during the years of 1990, 2007, and 2008. The chapter utilized remote sensing and GIS techniques for monitoring and mapping the drought risk in Sulaimaniyah governorate of Kurdistan region, Iraq. The NDVI, LST, and TCW were derived from the Landsat images for 1990, 2007, and 2008, as well as to the SPI as spectral and meteorological based drought indices. The aforementioned indices were used for monitoring the droughts and their impacts in the study area. The combination of the NDVI-SPI indices was suggested in this chapter to assess and map the drought risk in Sulaimaniyah. The results revealed a significant increase in the total areas of extreme, severe, moderate drought classes in 2008 by a percentage of 81.2% more than in 2007. Moreover, Dukan Lake's surface area in Sulaimaniyah suffered a significantly shrunk by 16.5% and 32.5% in 2007 and 2008, respectively, compared with its total size in 1990.

1.6 Remote Sensing and GIS for Natural Resources

The technical aspects of this theme is covered in five chapters from Chaps. 16 to 20. Chapter 16 presents a geo-morphometric analysis and flood simulation of the Tigris River due to a predicted failure of the Mosul Dam. Since GIS, RS, hydrologic and hydraulic modeling systems are capable of integrating each other to perform required hydrologic and hydraulic investigation and analysis precisely. Therefore, in this chapter through a specific schematic workflow the methodology of this research is applied in an efficient and reliable way. In this study, remotely sensed images such as DEM, topographic maps, Landsat satellite image, and tabulated hydrograph data are used. Thus, obtained geo-morphometric parameters for the Mosul Dam River-Basin are tabulated. Also, the discharge flow based on unsteady flow analysis is simulated based on a computational-2D program which is so-called HEC-RAS in order to calculate related hydraulic parameters such as time of arrival, flood depth, water surface elevation, and stream power and to delineate flooded zone inside Mosul city, Iraq as well. The obtained result from this study compared to the previous studies SWISS 1984, IWTC 2009 and JRC 2016 show good agreement with those of authors, specifically with the results of the SWISS study which is more detailed comparatively.

The present predictions indicate that the initial flood wave will reach the Mosul city in around 2 h and the height of the flood wave will reach approx. 24 m within 8 h, while the average flood velocity is predicted to be 3.9 m/s.

On the other hand, Chap. 17 explain how to use the DEM and raster images to effectively managed the water resources in the Kurdistan region of Iraq for hydrologic and hydraulic modeling of the Greater Zab River-Basin. Digital elevation model (DEM) and raster images are used as essential raw data to build reliable modeling systems. The schematic workflow of this chapter shows the methodology that is applied in order to create computational hydrologic and hydraulic modeling systems. This methodology includes two main stages of processing; pre-processing of data and post-processing. In the first stage, both geo-morphological and hydrological feature classes are obtained and calculated by using ArcGIS tools such as Arc Hydro, HEC-GeoHMS, and HEC-GeoRAS. While, in the second stage, 2D-simulation programs such as HEC-HMS and HEC-RAS are used for creating both hydrologic and hydraulic modeling systems respectively. This chapter shows the results that have been obtained. First, the main hydrologic feature classes such as (basin, watersheds, sub-watersheds, catchments, streams, and rivers) are extracted from the digital elevation model. Thus, the main geo-morphometric parameters for the Greater Zab watershed are calculated. Second, the hydrologic model is designed for calculating Rainfall-Runoff and performing floodplain analysis.

In Chap. 18, authors present how to use the Standardized Precipitation Index (SPI) and GIS Techniques to assess spatially drought conditions over Iraq. Assessment of drought conditions in Iraq is a very important task because of its location in the arid and semi-arid region. To assess and monitor drought conditions in Iraq, monthly complete precipitation data from 18 weather stations for the period (1980–2010) have been used to calculate Standardized Precipitation Index (SPI) using SPI Generator software. Statistical analysis has been done for SPI data to calculate averages, counts, minimum, maximum, and frequency values of dry and wet conditions at each station. Statistical data have been joined with the location of weather stations in ArcGIS for mapping SPI. The IDW interpolation is used with specific parameters for mapping SPI average and SPI wet and dry frequencies data. The maps show that SPI frequency for wet and dry conditions give better and real spatial distribution and variation rather than average of SPI. Time series figures and summarize table for selected weather stations in Iraq were used to analyse the trend, duration, and frequency of wet and dry periods.

The SPI values indicate there are three main drought periods that have happened in Iraq in (1984, 1999, and 2008). The interval time between drought periods is decreased in recent years. Using the frequency of wet and dry SPI is better for mapping than average SPI.

While Chap. 19 is interested in assessing the impacts of climate change on natural resources with a focus on the Erbil area, in the Iraqi Kurdistan region using geo-information and Landsat data. It aims to quantitatively study the large-scale semi-aridization of the climate in the Kurdistan region of Iraq, revealed by the rise of temperatures and consequently a decline in the precipitations volume. It aims to quantify the spatial and temporal dynamics of LULCC, in particular, the changes in vegetation, surface water and urban and built-up areas in the study area.

Nowadays, the Kurdistan region of Iraq faces a large-scale semi-aridization of the climate, with negative effects visible, among others, in the desiccation of vegetation cover and surface water.

This critical situation was the main reason to develop this work, whose aim was to set up proper methods and perform a retrospective analysis about climate changes and LULCC that occurred in more than two decades (1992–2014) in Erbil Area. Attention was devoted to analyzing the role of climate change and urban and built-up areas expansion on the degradation of vegetation cover and surface water in this area.

The analysis was based on (i) the Modified Normalized Difference Water Index (MNDWI) to extract the water surface, and on (ii) the Modifies Soil Adjusted Vegetation Index 2 (MSAVI2) to extract the areas of vegetation cover. Then the authors measured the positive and negative and null changes between the two considered epochs; a segmentation classification was also used for extracting urban and built-up areas expansion and for quantifying their impacts on other land covers.

As regards climate data, spring and summer seasons were mainly affected by temperature increase and rainfall decrease; the vegetation cover was lost for more than 50%, mainly for both these climate change effects (>94%) and for the small remaining part (<6%) for urban and built-up areas expansion. Similarly, the surface water resources also suffered a strong reduction (>41%) due to the increase in temperatures and decrease of rainfall.

Due to the importance of forest as natural resources, Chap. 20 is devoted to mapping forest-fire potentiality using remote sensing and GIS with focus on Kurdistan region-Iraq as a case study. A forest fire is considered as an important issue for the environmental, economy, population, and human safety in many forested areas in the world. Satellite remote sensing (RS) is today regarded as the main source of data for mapping fire risk, assessing forest fuel, monitoring forest fires, as well as, estimating post-fire damages. This chapter, getting aid from the priceless ability of RS and GIS techniques, is aiming to provide a map to show the potentiality of fires among the Kurdistan region forest and rangeland areas. Two sets of data, fields data (the location and date of fires in 2014 and 2015), and satellite data (MODIS NDVI-product time-series) were used. It has been proposed in many studies to use the NDVI variations in order to estimate the proneness of vegetation to fire. By classifying the NDVI image by a supervised classification (the maximum likelihood method), using the ENVI software, a classified image produced based on the satellite images which was acquired in August 2010. This classified image was regarded as the fire potential map. Then, the location of the fires from 2014 to 2015 were added to the map. The result showed there is a high level of overlap between the fired locations recorded in 2014 and 2015, and the areas named as very high and high fire-potential areas on the developed map.

The book ends with the conclusions and recommendations Chap. 21.

Acknowledgements The editors who wrote this chapter would like to acknowledge the authors of the chapters for their efforts during the different phases of the book including their inputs in this chapter.

References

Al-Agidi WK (1976) Proposed soil classification at the series level for Iraqi soils. I. Alluvial Soil. Baghdad University, College of Agriculture. Tech. Bull, no. 2

Attema EPW, Ulaby T (1978) Vegetation modeled as a water cloud. Radio Sci 13(2):357–364. https://doi.org/10.1029/RS013i002p00357

Part II
Soil Characterization, Modelling, and Mapping

Chapter 2
Using Radar and Optical Data for Soil Salinity Modeling and Mapping in Central Iraq

Weicheng Wu, Ahmad S. Muhaimeed, Waleed M. Al-Shafie and Ayad M. Fadhil Al-Quraishi

Abstract As one of the environmental calamities, soil salinization has become a key concern in agricultural management, especially, in irrigated areas in dryland systems. How to quantify and map soil salinity in space and time to provide relevant advices for decision-makers and land managers for their agricultural development has become a pressing issue. Based on our previous works, this study was aimed to develop rather simple and operational approaches for such quantification and mapping taking the Mussaib site in Central Iraq as an example. In conjunction with the field samples, ALOS (Advanced Land Observing Satellite) PALSAR (Phased Array L-band Synthetic Aperture Radar) data and Landsat 5 TM (Thematic Mapper) imagery acquired at almost the same time were employed for this purpose. After derivation of different biophysical indicators from the TM images and removal of the impacts of vegetation water content (VWC) on the L-band radar backscattering coefficients, a multivariate linear regression (MLR) modeling was applied to establish the combined and radar-based soil salinity models. Results revealed that VWC removal procedure could significantly improve the correlation between the measured apparent soil salinity (ECa) and radar backscattering coefficients by 7.5–25.6%. The optical-radar combined models can reliably predict soil salinity with an accuracy of 77.0–83.7% ($R^2 = 0.770$–0.837). Merely, further improvement in reducing the impacts of vegetation cover and soil moisture by radar data themselves is still recommended. In conclusion, the optical-radar combined approaches and models developed in this chapter shall

W. Wu (✉)
Key Laboratory of Digital Land and Resources, East China University of Technology, Nanchang 330013, Jiangxi, China
e-mail: wuwc030903@sina.com; wuwch@ecit.cn

A. S. Muhaimeed
College of Agriculture, University of Baghdad, Baghdad, Iraq

W. M. Al-Shafie
GIS Division, Ministry of Agriculture, Baghdad, Iraq

A. M. F. Al-Quraishi
Department of Environmental Engineering, College of Engineering, Knowledge University, Erbil 44001, Kurdistan Region, Iraq

A. M. F. Al-Quraishi and A. M. Negm (eds.),
Environmental Remote Sensing and GIS in Iraq, Springer Water,
https://doi.org/10.1007/978-3-030-21344-2_2

be operational for soil salinity modeling and mapping; and radar-based approach has great potential for this purpose.

Keywords Soil salinity · ALOS L-band radar · Landsat TM · Modeling and mapping · Central Iraq

2.1 Introduction

Soil salinity has become one of the most active land degradation phenomena in Central and Southern Iraq since the Babylonian period (Jacobsen and Adams 1958; Buringh 1960; Wu et al. 2014a, b). It is estimated that approximately 60% of the cultivated land has been seriously affected by salinity, and 20–30% abandoned in Mesopotamia (Buringh 1960; Wu et al. 2014a, b). Even in the non-abandoned agricultural land, crop yield has declined by 30–60% compared to the normal ones as a consequence of salinization. This unfavorable biophysical process has led to a conversion of the most highly productive land into the salinized land and provoked negative impacts on crop production and food security in the country. It is hence of prime importance to investigate the distribution and intensity of soil salinity in space and time and analyze the causes of salinization to provide relevant advices and suggestions for decision-makers in agriculture management and development.

Regarding the soil salinization in Iraq, several authors have conducted analyses, and mapping works, for example, Jacobsen and Adams (1958), Buringh (1960), Dieleman (1963), Al-Layla (1978), Al-Mahawili (1983), and Abood et al. (2011). Buringh and the Ministry of Agriculture (MoA) in Iraq had jointly undertaken soil classification and produced a soil map of Iraq in 1960. The Food and Agriculture Organization of the United Nations (FAO) investigated soil salinization severity while assessing the irrigation condition in Western Asia including Iraq in 2008 (FAO 2008). However, outdating and low resolution of the available maps (e.g., soil map dated 1960 with a resolution of 5–10 km) cannot meet the requirement of land management and salinity control at the farm- and local-scale in the region. Recently, funded by the Australian Agency for International Development (AusAID), the International Center for Agricultural Research in the Dry Areas (ICARDA) has conducted an Integrated Soil Salinity Management Project in Central and Southern Iraq.[1] The project was implemented in cooperation with the MoA, Ministry of Water Resources (MoWR), Ministry of Science and Technology (MoST), and Ministry of Education (MoE) of the Iraqi Government in the period 2010–2014. Soil salinity modeling, quantification and mapping were one of the main tasks of the project. Based on field survey and multiyear optical remote sensing data, successful studies on salinity modeling and mapping with high reliability have been achieved in Mesopotamia (Wu et al. 2012, 2014a, b; Muhaimeed et al. 2013).

[1] https://www.icarda.org/iraq-salinity-project.

With application of optical remote sensing, several mature approaches for soil salinity mapping have been developed and discussed in the recent decades (Dwivedi and Rao 1992; Mougenot et al. 1993; Rao et al. 1995; Metternicht and Zinck 2003; Farifteh et al. 2006, 2007; Eldeiry and Garcia 2010; Wu et al. 2014a, b; Bannari et al. 2018). These approaches focused on best band combination, multiyear maxima-based multivariate modeling and quantification, etc. Some authors have even explored the possibility to detect soil salinity by microwave radar data as they are independent of weather condition (Sreenivas et al. 1995; Taylor et al. 1996; Shao et al. 2003; Aly et al. 2004; Lasne et al. 2008; Gong et al. 2013). The laboratory-based simulations by Shao et al. (2003), Lasne et al. (2008) and Gong et al. (2013) suggested that it is possible to use the microwave C-band, and especially L-band for detecting salinity in different settings. Because the radar signal can penetrate through the surface and reach subsoil at a depth of, e.g., >50–150 cm, depending on the wavelength or frequency of the emitted waves and soil moisture. They concluded that the real part of the soil dielectric permittivity is responsive to the moisture, and its imaginary part is associated with both soil moisture and salinity. However, successful and satisfactory radar-based salinity modeling and quantification have been rarely reported probably due to the difficulty to separate soil salinity from soil moisture, or rather, to remove the impacts of soil moisture and vegetation cover on the salinity part of the radar backscattering coefficient.

In view of this difficulty, our intention was to incorporate radar data, taking their advantages of independence of weather condition and penetration to subsoil, with optical imagery for salinity assessment. As a matter of fact, it has been reported that significant improvement in accuracy of land cover mapping had been achieved by combing radar with optical data (Li et al. 1980; Pereira et al. 2013), or a higher efficiency reached by adding radar data while assessing irrigation, soil moisture and crop performance (Clevers and van Leeuwen 1996; Moran et al. 1997; Fieuzal et al. 2011; He et al. 2014).

For this reason, the main objective of this study was to ascertain the possibility to propose a simple and operational approach for soil salinity assessment by combing both radar and optical data as a complement to the available optical ones. The specific objectives were (1) to develop combined soil salinity model(s) by incorporating radar backscattering coefficient (σ) with biophysical indicators from optical data, and (2) to explore the potential to develop radar-based model(s) for the same purpose. The research was implemented in the Mussaib site in Central Iraq where we had already conducted salinity modeling and mapping using multiyear optical remote sensing data (Muhaimeed et al. 2013; Wu et al. 2014a, 2018).