SJIF IMPACT FACTOR (2015): 5.42 CRDEEP Journals
International Journal of Basic and Applied Sciences Abuelgasim & Ammad Vol. 6 No. 4 ISSN: 2277-1921
International Journal of Basic and Applied Sciences. Vol. 6 No. 4. 2017. Pp. 145-150

Full length Research ***Paper***

Mapping Sabkha Land Surfaces in the United Arab Emirates (UAE) using LANDSAT 8 Oli Visible Data

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Article history
Received: 30-07-2017
Revised: 08-08-2017
Accepted: 14-08-2017

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Abstract
The UAE is home to some of the largest concentrations of sabkhas both coastal and inland. Sabkha is an Arabic word for a salt-flat area found mainly along arid area coastlines and inlands within sand dunes areas. Detecting and mapping sabkha land surfaces from satellite data is an arduous process. Most classification techniques of multispectral data alone, usually fail to properly identify sabkha pixels or provide lower rates of mapping accuracy for sabkha surfaces. The primary objective of this research is to develop a much more accurate methodology for properly mapping and identifying sabkha areas from remotely sensed data. Properly mapping sabkha surfaces from remotely sensed data is the first steps towards studying the ecological changes within such surfaces using earth observation techniques. Furthermore, sabkha surfaces can in certain situations be a geotechnical hazard due to its highly salinity and with adverse effects on concrete, asphalt, steel and other structures, in addition to their sporadic heaves and collapses. As the UAE continue to build major infrastructure and development projects identifying the location of such surfaces is vitally important. In this study, a sabkha index is developed based on the visible spectrum information provided by Landsat 8 OLI. The index was accurately able to identify sabkha polygons within the study area at an accuracy of 75% in comparison to other soil salinity indices using the same spectral information (62.5%).

Key words: *Sabkha, Soil Salinity, Landsat 8, UAE*

Introduction

Sabkha are salt flats associated with hot and arid climate, typically formed in shallow continental shelf/ marine environment (G. Evans .1970; Kendall et. al. 1994). They are classified as inland sabkhas, present within the sand dunes, or coastal sabkhas, found on shoreline and distinguished based on formation in varying tidal environments; 1) sub-tidal flats, 2) lagoons and intertidal flats, 3) supratidal flats (Pain & Abdelfattah, 2015; Shinn, 1983). Inland sabkhas that form within the sand dune areas are relatively flat and highly saline areas of sand or silt formed just above the water-table where the sand is cemented together by evaporite salts from seasonal ponds. Coastal sabkhas are characterized by evaporite deposits, which may consist of carbonates or siliciclastic.

The primary objective of this research study is to develop a new technique for mapping inland sabkha surfaces using multispectral remotely sensed data. Identifying sabkha pixels in remotely sensed images has been quite an arduous process (Allbed and Kumar 2013). This is primarily due to the confusion of sabkha pixels with saline soils and the mixture of sabkhas with sand dunes making spectral separation a challenging process (Ammad and Abuelgasim, 2016). This research uses the multispectral information provided by Landsat 8 data in addition to a set of transformed multispectral data including principal components and a sabkha to accurately identify sabkha pixels from other land cover pixel types.

Materials and Methods

Study Area

The climate of the area is hot, dry and arid with scarce amount of annual rainfall around 72 mm (Raafat, 2007) and rates of evaporation exceeding 2000 mm per year (Paul, Al Tenaiji, & Braimah, 2016). This high evaporation rate accounts for salinities ranging from 37% near Strait of Hormuz and 65% in the Arabian coastal lagoons (Alsharhan & Kendall, 2003; Bathurst, 1975) whereas in shallow depths of UAE coastal areas the average salinities vary from 40-50% and in lagoons and embayments they can reach up to 60-70%(Evans, Schmidt, Bush, & Nelson, 1969). The temperature 25cm below the sabkha goes up to 17°C in winters and 43°C in summers respectively (Lokier, Knaf, & Kimiagar, 2013). The Shamal wind is the prominent climatic feature of the area, which blows in north-west direction. Storm outbreaks result in shallow inundation of the coastal area due to ramp geometry of coastline.

Geologic Setting of Sabkha

Main contributors to sabkha formation in the study area are the eustatic sea levels in the late Quaternery (Stevens, Jestico, Evans, & Kirkham, 2014) and north (Shamal) winds and currents which resulted in erosion of Pleistocene sand dunes some 7000 years ago (Evans et al., 1969). On northern coast of UAE, Sabkha emerged as a product of global sea-transgression and regression cycles during the latter part of Pleistocene time. About 12000-10000 years ago, (Kassler, 1973, R. Weijermars.1999) sea level began to rise reaching a little above its present level around 4000 years ago, meanwhile flooding the depressions between coastline and dessert sand dunes.

Salt flats and depressions formed at the time of this fluctuating sea level and simultaneous erosion of late Quaternary (Al-Hurban and Gharib, 2004). Carbonates deposited on the seabed during phases of flooding and shriveled once the water retreated. Carbonate sand dunes evolved as the strong winds blew following the transgression-regression cycles. High evaporation rates made the soil, salt-concentrated, which eventually caused formation of a halite crust that expanded laterally as it desiccated and retained the shape of polygon, uplifting the margins. Fluids inside the sediments crystalized gypsum as they saturated with calcium sulphate. (Al-Farraj, 2005; Pain & Abdelfattah, 2015) has described the evolution of sabkha in the study area in 6 phases, based on different tidal environments including subtidal flats (khors) and intertidal channels, lagoons (intertidal flats) and supratidal flats (Pain & Abdelfattah, 2015). Coastal sabkha run for about 24 km inland between Abu Dhabi and Umm al Qawain and Sabkha Matti, the largest sabkha, extends for 150 km in the northern Rubal Khali Desert (Edgell, H. S. 2006). These inland sabkha exist in form of secluded interdunal plains, that flood during heavy rainfall and are characterized by intertwined polyhedrons of sand and gypsum (Brown, 2006). Coastal sabkha are dominated by carbonate sands, contrary to inland sabkha which are siliclastic in nature (Alsharhan & Kendall, 2003).

Studying Sabkha through Remote Sensing

Sabkha, as described earlier, develop in response to high evaporation rates, which result in supersaturation of soils with insoluble salts (Al-Jaloud and Hussain 2006). This associated soil salinity is used for identifying sabkhas through remotely sensed data; either directly by recognizing exposed salt topographies or indirectly by pinpointing the vegetation related to saline soils. Multispectral satellite imagery is the most commonly used and conveniently available technique for mapping saline soils (Allbed and Kumar 2013) in which maximum effectiveness is achieved with less than 5m pixel size (R. Dwivedi, et al. 2008). In addition to multispectral sensors, there is also a more sophisticated alternative available for mapping the saline soils, in form of hyperspectral sensors. These sensors have better spatial and spectral resolution compared to multispectral sensors and they are able to capture variations in salinities much more comprehensively.

It is significant to note that salt reflectance is dependent on a number of factors such as salt type, mineralogy, color, and surface roughness (Mougenot et al. 1993). Usually, the more the amount of salt in soil the higher is the reflectance and vice versa. Spectral sensitivity of highly saline soils lies in the range of visible and near-infrared part of spectrum and hence the salt features can be interpreted through multispectral data using this knowledge. Similarly, to differentiate between the salt mineralogy, thermal bands in the electromagnetic spectrum are used (Allbed and Kumar 2013). (Sadiq & Howari, 2009) used VNIR (visible and near-infrared) spectrum to distinguish between sabkha sands, beach sands and aeolian dune sands and concluded that sabkha sands, mainly composed of quartz, gypsum and salts, show low (20-30%) TM reflectance in visible and near infrared (1-4 bands) but increased reflectance in band 5 in the near infrared.

Study Area and Satellite Data

The study area represents the western parts of the city of Abu Dhabi and the western extremities of the UAE. This area in particular is home to some of the largest sabkha surfaces in the world. It includes both coastal sabkhas and inland sabkhas that can be found within proximity of tens of kilometers from the coast. The multispectral data used in the study come from Landsat 8 path 161 and row 43 collected on July 15th 2015. The study utilizes Landsat 8 spectral bands 2-7 to develop the principal components and later only use bands 3 and 4 for developing a sabkha spectral index. Figure 1 shows the study area.

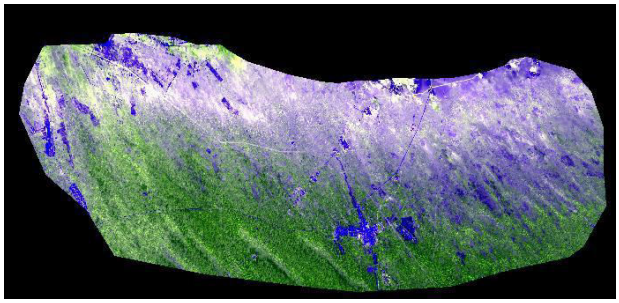


Fig 1: Study Area

Methodology

The first step in the image processing was to perform the atmospheric correction for the Landsat 8 data. The FLAASH program in ENVI that utilizes the MODTRAN atmospheric correction algorithm was used for the correction of the data. A principal component transformation was applied to the atmospherically corrected data. Principal components analysis (PCA) is a statistical technique

through which any original set of data is transformed into a new set of data that is expected to capture and condense the key valuable information in the original set of data. In many situations, the information contained with a data set is highly auto-correlated and redundant. The PCA transformation condenses the full data set information into few variables that are un-correlated and orthogonal to each other. The application of PCA to satellite image data usually results in few components that contains condensed information from all the spectral bands used.

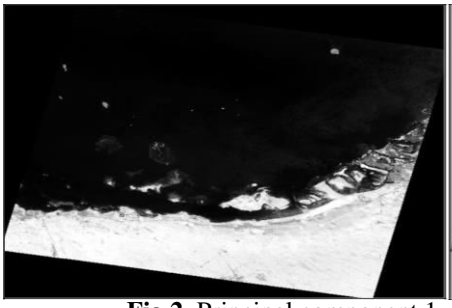
Results and Discussion

Six components resulting from the transformation were carefully analyzed to identify if any of the components was particularly portraying sabkha pixels in comparison to other land cover types. The analysis was done through visual interpretation of the images and the analysis of the transformation eigenvectors. The resulting transformation eigenvectors of covariance matrix as shown in Table 1.

Table 1: Eigenvectors of the covariance matrix of the principal component transformation

	Band 2	Band 3	Band 4	Band 5	Band 6	Band 7
PC1	0.20	0.29	0.38	0.46	0.55	0.46
PC2	0.53	0.53	0.29	0.08	-0.35	-0.47
PC3	-0.38	-0.24	0.11	0.73	-0.01	-0.50
PC4	0.57	-0.24	-0.53	0.09	0.48	-0.31
PC5	0.30	-0.18	-0.32	0.46	-0.58	0.47
PC6	-0.35	0.69	-0.61	0.15	0.06	0.00

Of particular importance and relevance were components 1 and component 6. The first component represented the overall scene brightness. Desert surface appear bright, with varying levels of brightness among the different desert surfaces and water bodies appeared darker in comparison to desert surfaces. Previously knowledge of the exact location of certain sabkha helped the interpretation of principal component 6. Component 6 showed sabkha pixels in extremely darker tones in comparison to any other land cover type, which suggests that this component is strongly related to the presence of sabkhas at these pixels. As expected the sabkha pixels in component 6 showed high levels of brightness in component due to the brighter nature of the salt body within these pixels. Figure 2 and 3 show the two principal components.



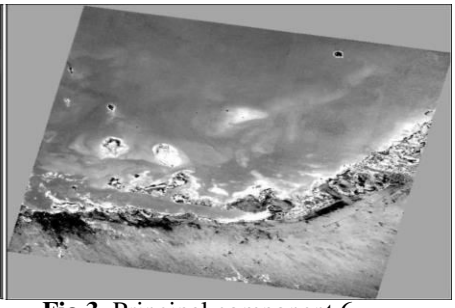


Fig 2. Principal component 1 **Fig 3.** Principal component 6

Principal component 6 carries high loading factors for spectral bands 3 and 4 of Landsat 8. This suggests strong correlation between the reflected radiation in the green and red parts of electromagnetic spectrum and the presence of sabkhas or saline areas (Douaoui et. al 2006). A sabkha index can be developed from this relation that takes into account the sabkha reflectance in the green and red parts of the spectrum. High index values confirm strong presence of sabkhas. It is necessary to apply a threshold to separate high values from non sabkha index values. The developed index took the form of

Sabkha Index = Green Reflectance/Red Reflectance

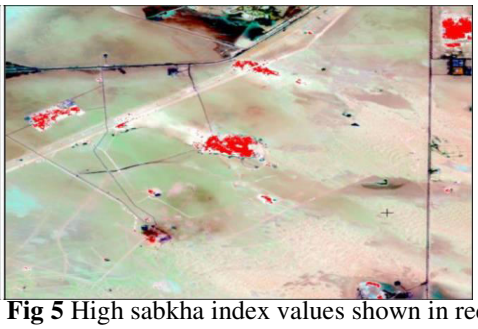


Fig 4. Sabkha Area (bright white pixels) **Fig 5** High sabkha index values shown in red

The index calculation was applied for a selected area of the image with known discrete sabkhas as shown in Figure 4. Figure 5, shows the index high values associated with sabkha pixels shown in red. There is a strong agreement between the two images where most

sabkhas in Figure 4 are properly identified in Figure 5 as red pixels. The missing pixels not identified as sabkhas in Figure 5 are due to the threshold cutoff point.

The developed index was applied to the Landsat 8 OLI image for particular part of the image that excludes the water and coastal areas. Figure 6 and 7 show the original index image along with the resulting sabkha pixels meeting the threshold value shown in red. In the original index image sabkha pixels show as white areas mostly to the north and north-western part of the study area (figure 6). There is a reasonable agreement between the two images where most bright pixels in figure 6 are selected as sabkha pixels in figure 7.

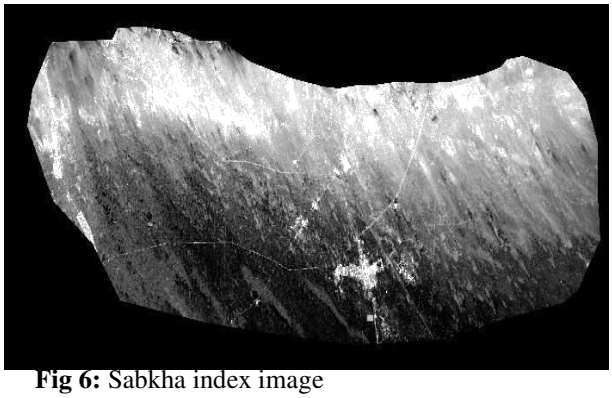


Fig 6: Sabkha index image

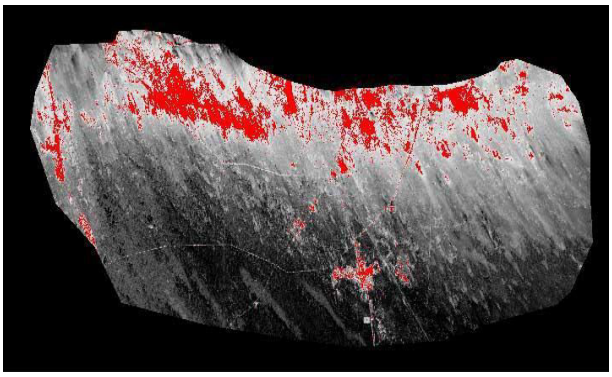
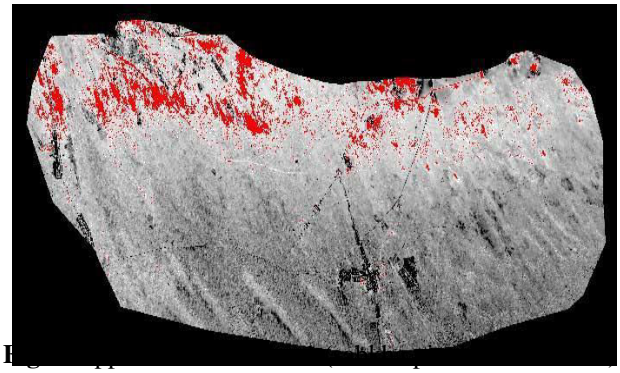


Fig 7: Sabkha index image with sabkha pixels shown in red



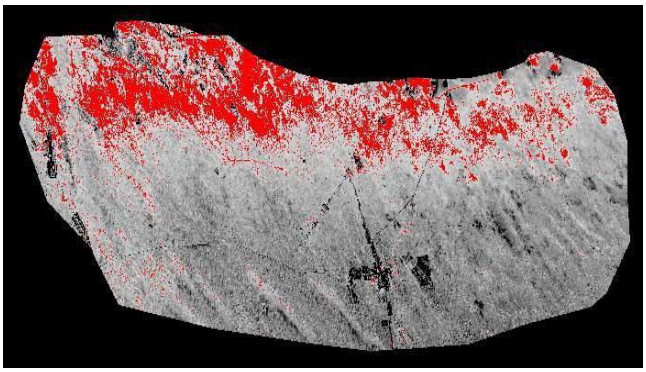


Fig 9: Application of Index 2 (sabkha pixels show in red)

To compare the resulting index results two indices that are widely used in mapping soil salinity are investigated. The two indices (Index 1 (Douaoui et. al. 2006) and Index 2 (Abbas and Khan 2007)) use the same spectral information as the sabkha index.

Index 1 = Square_root (Green Reflectance X Red Reflectance)
Index 2 = Square_root (Green Reflectance^2 + Red Reflectance^2)

Figure 8 shows the resulting application of index 1 to the Landsat 8 OLI image data while figure 9 shows the application of index 2.The sabkha index developed in this study appears to have reasonable agreement with the actual sabkha area in the image. Index 1 is showing less sabkha pixels and appears to be missing a large part of the information while index two image shows that the index is over estimating the sabkha area.To further assess the accuracy of the three sabkha maps maps a field campaign was organized. The field survey was focused on assessing the accuracy of each index map. A total of 16 soil samples were selected within the study area in sabkha covered areas. From the 16 points sampled the sabkha index image identified correctly 12 points and missed 4 points not being labeled as sabkhas resulting in an overall accuracy of 75%. Index 1 and 2 identified 10 points correctly as sabkha pixels while missing 6 points from being labeled as sabkha resulting in an accuracy of 62.5%. The use of the sabkha index represented a significant improvement in mapping and identifying sabkha pixels from other land cover types.

Conclusion

A new index towards mapping and identifying sabkha areas is presented in this research developed through the application of image transformation and PCA. Image transformation processes such as principal component analysis and spectral indices development helps to identify patterns in the data that would not be obvious from the analysis of the multispectral data only. Image transformation processes help transform the original bands into "new" images which better display or highlight certain features in the scene. Accurate mapping and identifying sabkha areas is a crucial step for mapping the environmental change in sabkha surfaces. This work will be further improved by using much finer spatial resolution data and the collection of more field sabkha pixels for accuracy assessment.

The field work in this study was limited to 16 points only due to the extreme weather and heat conditions in the desert during the summer time.

References

Abbas, A and S. Khan, "Using Remote Sensing Techni- Open Access *ARS* A. ALLBED, L. KUMAR Open Access *ARS* 385 ques for Appraisal of Irrigated Soil Salinity," In: L. Oxley and D. Kulasiri, Eds., *International Congress on Model- ling and Simulation* (*MODSIM*), Modelling and Simula- tion Society of Australia and New Zealand, Brighton, 2007, pp. 2632-2638.

Abed, R. M., Kohls, K., Schoon, R., Scherf, A. K., Schacht, M., Palinska, K. A. & Golubic, S. (2008). Lipid biomarkers, pigments and cyanobacterial diversity of microbial mats across intertidal flats of the arid coast of the Arabian Gulf (Abu Dhabi, UAE). FEMS microbiology ecology,65(3), 449-462.

Allbed, A., & Kumar, L. (2013). Soil salinity mapping and monitoring in arid and semi-arid regions using remote sensing technology: a review. Advances in Remote Sensing, 2013.

Al-Farraj, A. (2005). An evolutionary model for sabkha development on the north coast of the UAE. Journal of Arid Environments, 63(4), 740-755. doi:http://dx.doi.org/10.1016/j.jaridenv.2005.01.025

Al-Hurban, A., & Gharib, I. (2004). Geomorphological and sedimentological characteristics of coastal and inland sabkhas, Southern Kuwait. Journal of arid environments, 58(1), 59-85.

Al-Jaloud, A. A., & Hussain, G. (2006). Sabkha ecosystem and halophyte plant communities in Saudi Arabia. In *Sabkha ecosystems* (pp. 1-7). Springer Netherlands.

Alsharhan, A. S., & Kendall, C. S. C. (2003). Holocene coastal carbonates and evaporites of the southern Arabian Gulf and their ancient analogues. Earth-Science Reviews, 61(3), 191-243.

Ammad, R., & Abuelgasim , A. (2016). Comparative Analysis Of Salinity Indices For Mapping Sabkha Surfaces In The United Arab Emirates (UAE). In, 37th Asian Conference on Remote Sensing (ACRS): Promoting Spatial Data Infrastructure for Sustainable Economic Development. Colombo, Sri Lanka.

Bathurst, R. G. C. (1975). Carbonate sediments and their diagenesis. Developments in Sedimentology, 12.

Bontognali, T. R., Vasconcelos, C., Warthmann, R. J., Bernasconi, S. M., Dupraz, C., Strohmenger, C. J., & McKenzie, J. A. (2010). Dolomite formation within microbial mats in the coastal sabkha of Abu Dhabi (United Arab Emirates). Sedimentology, 57(3), 824-844.

Brown, G. (2006). The sabkha vegetation of the United Arab Emirates. In M. A. Khan, B. Böer, G.
S. Kust, & H.-J. Barth (Eds.), Sabkha Ecosystems: Volume II: West and Central Asia (pp. 37-51).
Dordrecht: Springer Netherlands.

Douaoui, A.E.K, Nicolasb, H. and Walter, C. "Detecting Salinity Hazards within a Semiarid Context by Means of Combining Soil and Remote-Sensing Data," Geoderma, Vol. 134, No. 1-2, 2006, pp. 217-230. http://dx.doi.org/10.1016/j.geoderma.2005.10.009

Edgell, H. S. (2006). Arabian deserts: nature, origin and evolution. Springer Science & Business Media.

G. Evans Coastal and nearshore sedimentation: a comparison of clastic and carbonate deposition Proceedings of Geological Society of London, 81 (1970), pp. 493–508

Evans, G., Schmidt, V., Bush, P., & Nelson, H. (1969). Stratigraphy and Geologic history of the Sabkha Abu Dhabi, Persian Gulf. Sedimentology, 12(1/2), 145

Glennie, K., Fryberger, S., Hern, C., Lancaster, N., Teller, J., Pandey, V., & Singhvi, A. (2011). Geological importance of luminescence dates in Oman and the Emirates: An overview. Geochronometria, 38(3), 259-271.

Kendall, C. G. S. C., & Skipwith, S. P. A. E. (1969). Geomorphology of a recent shallow-water carbonate province: Khor al Bazam, Trucial Coast, southwest Persian Gulf. Geological Society of America Bulletin, 80(5), 865-892.

Kendall, C.G, Alsharhan, A.S., and Whittle, G., 1994, Field Guidebook to Examine the Holocene Carbonates/Evaporites of Abu Dhabi, United Arab Emirates: for the International Geological Correlation Program (IGPCP-349): Abu Dhabi, U.A.E. University Publication Department, 46 p.

Kassler, P. (1973). The structural and geomorphic evolution of the Persian Gulf. In The Persian Gulf (pp. 11-32). Springer Berlin Heidelberg.

Lokier, S. W., Knaf, A., & Kimiagar, S. (2013). A quantitative analysis of Recent arid coastal sedimentary facies from the Arabian Gulf Coastline of Abu Dhabi, United Arab Emirates. Marine Geology, 346, 141-152. doi:http://dx.doi.org/10.1016/j.margeo.2013.09.006

Mougenot, B., Pouget, M., & Epema, G. (1993). Remote sensing of saltaffected soils. Remote Sensing Reviews , 7 , 241–259.

Pain, C. F., & Abdelfattah, M. A. (2015). Landform evolution in the arid northern United Arab Emirates: Impacts of tectonics, sea level changes and climate. CATENA, 134, 14-29. doi:http://dx.doi.org/10.1016/j.catena.2014.09.011

Paul, P., Al Tenaiji, A. K., & Braimah, N. (2016). A review of the water and energy sectors and the use of a nexus approach in Abu Dhabi. International journal of environmental research and public health, 13(4), 364.

Purser, B. H. (Ed.). (2012). The Persian Gulf: Holocene carbonate sedimentation and diagenesis in a shallow epicontinental sea. Springer Science & Business Media.

R. Dwivedi, *et al*., "5 Generation of Farm-Level Informa-tion on Salt-Affected Soils Using IKONOS-II Multispec-tral Data," In: G. Metternicht and J. Zinck, Eds., *Remote Sensing of Soil Salinization*: *Impact on Land Management*, CRC Press, Boca Raton, 2008.

Raafat, H. (2007). Climate (pp. 72–89). Physical Geography Sector Paper, Environment Agency Abu Dhabi.

Sadiq, A., & Howari, F. (2009). Remote Sensing and Spectral Characteristics of Desert Sand from Qatar Peninsula, Arabian/Persian Gulf. Remote Sensing, 1(4), 915-933. doi:10.3390/rs1040915

Shinn, E. A. (1983). Tidal flat environment. In Carbonate depositional environments (Vol. 33, pp. 171-210). American Association of Petroleum Geologists Tulsa.

Stevens, T., Jestico, M. J., Evans, G., & Kirkham, A. (2014). Eustatic control of late Quaternary sea-level change in the Arabian/Persian Gulf. Quaternary Research, 82(1), 175-184. doi:http://dx.doi.org/10.1016/j.yqres.2014.03.002

Weijermars, R. (1999). Quaternary evolution of Dawhat Zulum (half moon bay) region eastern province, Saudi Arabia. GeoArabia, 4(1), 71-90.