Application of SAR Data to the Mapping of Paleodrainages underneath Sand Sheets in the United Arab Emirates

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Abstract

The data from PALASAR L band and Spaceborne Imaging Radar-C/X-band Synthetic Aperture Radar (SIR-C/X-SAR) and the Shuttle Radar Topographic Mission sensors successfully reveals new paleodrainage system, which flows northwest and southwest through sand dune corridors of the United Arab Emirates and end up in the Arabian Gulf. The flow directions simulated automatically from the topographic data of Shuttle Radar Topographic Mission sensor using D8 algorithm confirms the presence of the discovered paleodrainage system that could have formed during flood seasons on the Oman Mountain during the late Quaternary. During late Quaternary the United Arab Emirates was dominated by two shallow paleodrainage systems that flowed into the Arabian Gulf, the NW-SE trending draining northern Emirates and the SW-NE trending draining Abu Dhabi and Dubai Emirates. The sand dune corridors along the linear sand dune aquifer are considered of good potential as it was received a considerable amount of rainwater during the late Quaternary. Detailed geophysical survey to sand dune corridors should beconducted for further estimation of the groundwater quality.

1 Introduction

The linear sand accumulation of the eastern Sahara and Ruba Al Khalei, including the United Arab Emirates originated by fluvial process and it was transported to the depressions and lowlands by palaeo-rivers. (El-Baz *el al.* 2000). He hypothesized that there is a spatial relationship between sand accumulation and the potential of sand accumulation in the eastern Sahra.

Several previous studies have shown that active remote sensing data such as Radarsat images (C band), ALOSAPLASR (L band), Shuttle Topographic Radar Mission STRM (C/X band) have the capability to penetrate extremely sand sheets up to 25cm and reveal subsurface paleodrianage systems (Elachi *et al.* 1984 and Farr *et al.* 1986). Several previous studies have been applied to map unknown paleodrainage channels and geological structures in the eastern Sahara from low frequency orbital Synthetic Aperture Radar (SAR) data (Abdelsalam and Stern 1996, Paillou *et al.* 2009; Samy and Mohamed 2013).

Farr *et al.* (2007) concluded that combining Shuttle Topographic Radar Mission (STRM) with SAR images better reveals subsurface paleodrainage underneath sand sheets. About 1300 of small craters-like structures were revealed in the southwester Egyptian desert using SAR data and ground penetration radar (Paillou *et al.* 2006). The availability of the Japanese PALSAR images (L band) allowed better detection and more details of subsurface paleodrainage networks in the Eastern Sahara (Paillou *et al.* 2007). Although several studies have been applied on the Eatsern Sharah, limited number has been done on the Arabian Peninsula.

In the Arabian Peninsula, extensive drainage systems originated in the Oman and Red Sea Mountains were flowing southwest-word, northwest word, northeast word to the great sand sea (Al Rub Al Khalie) and to the Arabian Gulf and the Red Sea. While this region is now arid, remains of paleodrainage systems underneath desert plains (sand dune corridors) have revealed from SAR data, leading Dabbagh *et al.* (1996) to propose some paleodrainage pathways in the Jafurah sand sea and Al-Labbah Plateau, Saudi Arabia . In this study, we used Shuttle

Topographic Radar Mission (STRM) DEM of spatial resolution of (~90m) and ALOS PALSAR images (L band) HH polarization of spatial resolution of 10m and Shuttle Imagine Radar (SIR-C) HH polarization of spatial resolution of 30m. We used these multi-sources of remote sensing data due their ability to penetrate sand sheets and reveal paleodrainage network underneath desert plains. We revealed and mapped several paleodrainage network in the desert plains (corridors of sand dunes), in the United Arab Emirates, which could have linked the Oman Mountain and sand dunes and Arabian Gulf since the Quaternary. The main objective of this study is to map and characterize paleodrainage network underneath desert plains and running along sand dune corridors.

3. Data and methods

Four remotely sensed datasets were employed in this study. The first data set was LANDSAT TM images of 30 m spatial resolution are currently available from the Global Land Cover Facility (glcf) by the University of Maryland database (ftp.glcf.umd.edu/glcf/Landsat). The second data set was the updated version of the Shuttle Radar Topography Mission (SRTM) DEM of ~90m spatial resolution is currently available in the database of the Consortium for Spatial Information (CGIAR-CSI) (http://srtm.csi.cgiar.org/Index.asp). The third data set was Spaceborn Imagine Radar- C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR) of spatial resolution of ~30m and are available from Earth Explorer of United Stat geological survey database (https://earthexplorer.usgs.gov). The fourth data set was PALSAR images (HH polarization (L band) of spatial resolution 10 m and provided by the Japanese Aerospace Exploration Agency (JAXA). As a first step in mapping of paleodrainages, the data were geometrically corrected and the noise in remote sensing data were eliminated by applying the enhanced Lee filter (Lee 1980) and 3x3 smooth filter. These multi-sources of remote sensing data were used to detect visually and automatically the buried paleodaianges underneath sand sheets and comparing the textural features evident and deciding if these patterns are different. The automatic detection of paleodrainages was performed using D8 algorithm (Jensen and Dominique 1988), which is previously used by Samy and Mohamed (2013) and implemented in Arc GIS software v9.1

4. Results

A set of multi-sources remote sensing data in terms of Shuttle Topographic Radar Mission DEM (~90 m), SIR-C/X SAR (30 m), ALOS-PALSAR (10 m) and LANDSAT (30 m) images permitted for the first time a precise mapping and characterizing of near surface paleodrainage network that are distributed in the sand dune corridors. Their upstreams are mainly in the Oman Mountain, flowing southwest to the sand dune field and its corridors. At the foot of Oman Mountain (alluvial plain), the longitudinal paleodrainage network run along wadi courses become parallel to each other, suggesting structural control. From the sand dune field, the paleodrainages run along sand dune corridors and clearly incises limestone bedrock (Al Nuaimi 2004).

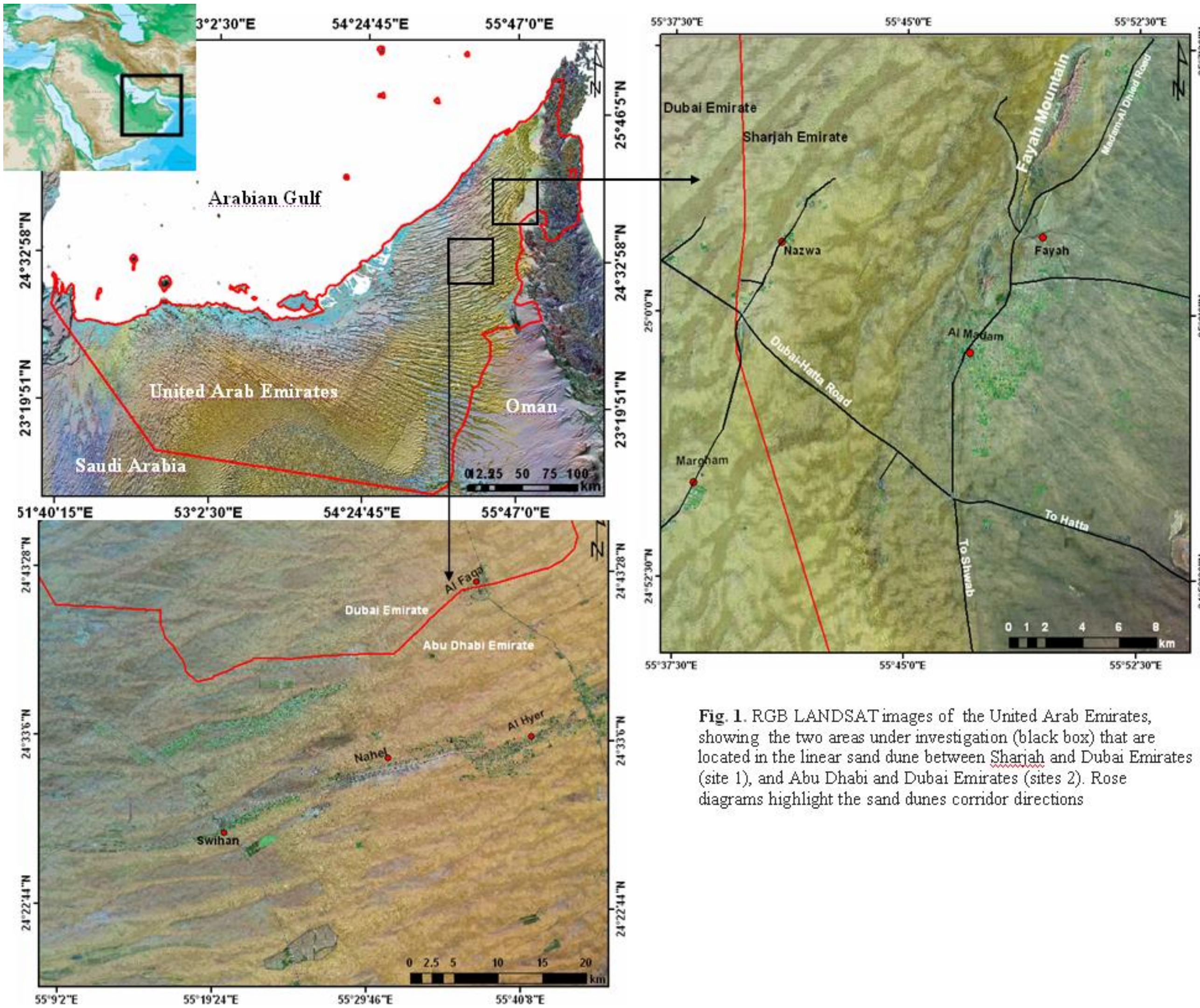

Fig. 1. RGB LANDSAT images of the United Arab Emirates, showing the two areas under investigation (black box) that are located in the linear sand dune between Sharjah and Dubai Emirates (site 1), and Abu Dhabi and Dubai Emirates (sites 2). Rose diagrams highlight the sand dunes corridor directions

They flow Wadi Shewab to Wadi Al Madam and Wadi Ar Rafeeah (northwest) with 27 km in length and join at the western side of Jabal Fayah and Melihah Mountains and disappear in sand dune (figures 1, 2).

In this later area, optical remote sensing data (thermal band) have revealed a lower temperature flux along the NW-SE paleodrainages that are structurally controlled (Ghoneim 2008). She found the groundwater temperature was approximately 8C lower than other parts of the study area. These flow directions are demonstrated in the National Atlas of the United Arab Emirates (1993) and Japanese International Corporation Agency report (1996). Farther south, in Abu Dhabi Emirate, two types of paleodrainages were identified and mapped from remote sensing data. The first type is longitudinal in shape and drains the northeast-southwest trending sand dune corridors over regional scale.

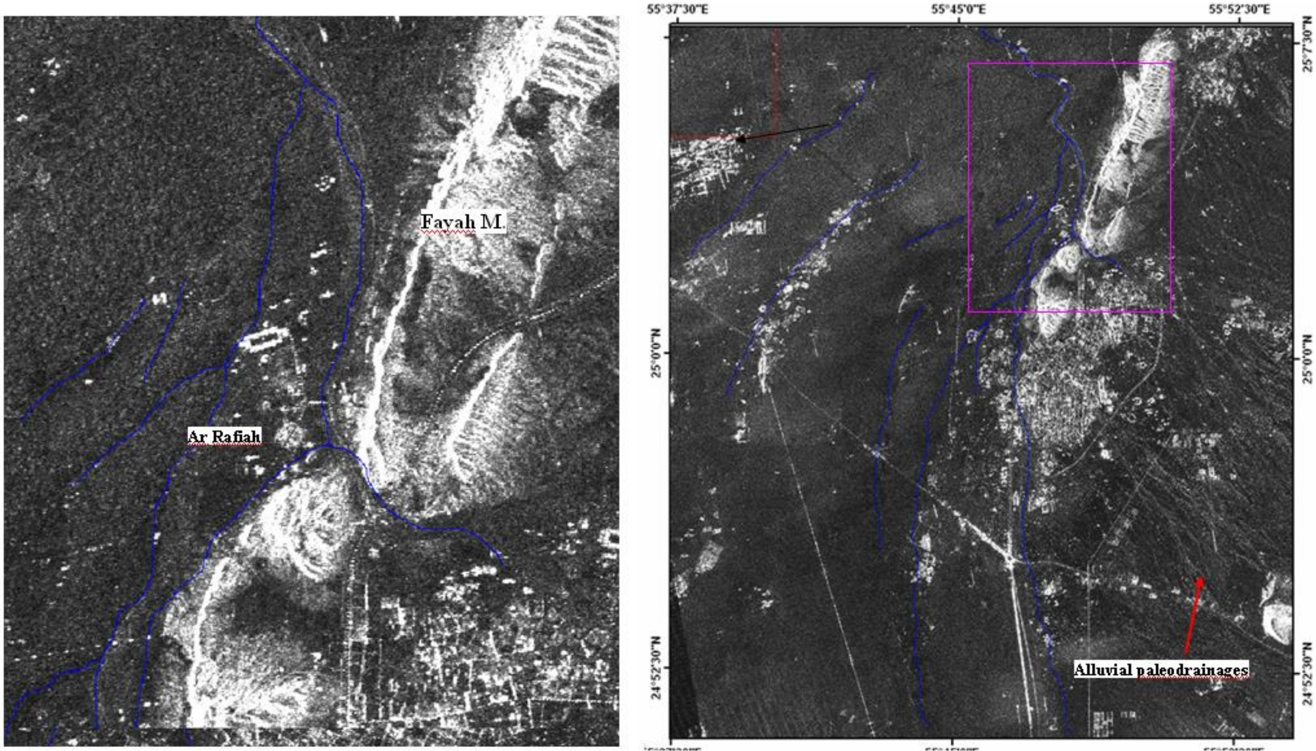

Fig.2. PALSAR images of the areas between Sharjah and Dubai Emirates (site 1). The bright lines represent alluvial paleodrainages and the dark signatures highlight sand dune paleodrainages, which join Wadi Ar Rafiah at the foot of Fayah Mountain

The second type is dendritic in shape and drains desert plains to the northwest over small scale (figure 3). They flow under the influence topographic slope and relief and bring the fragments of the ultra basic rocks from Oman Mountain, depositing coarse gravel to the alluvial plains and fine sediments to the desert plains and sand dunes corridors, so that the paleodrainages in alluvial plain have a bright signature in the alluvial plain (at the foot of Oman Mountain) and the paleodrainage in sand dune corridors and desert plains have a dark signature in LANDSAT and radar images (figures 2 and 3).

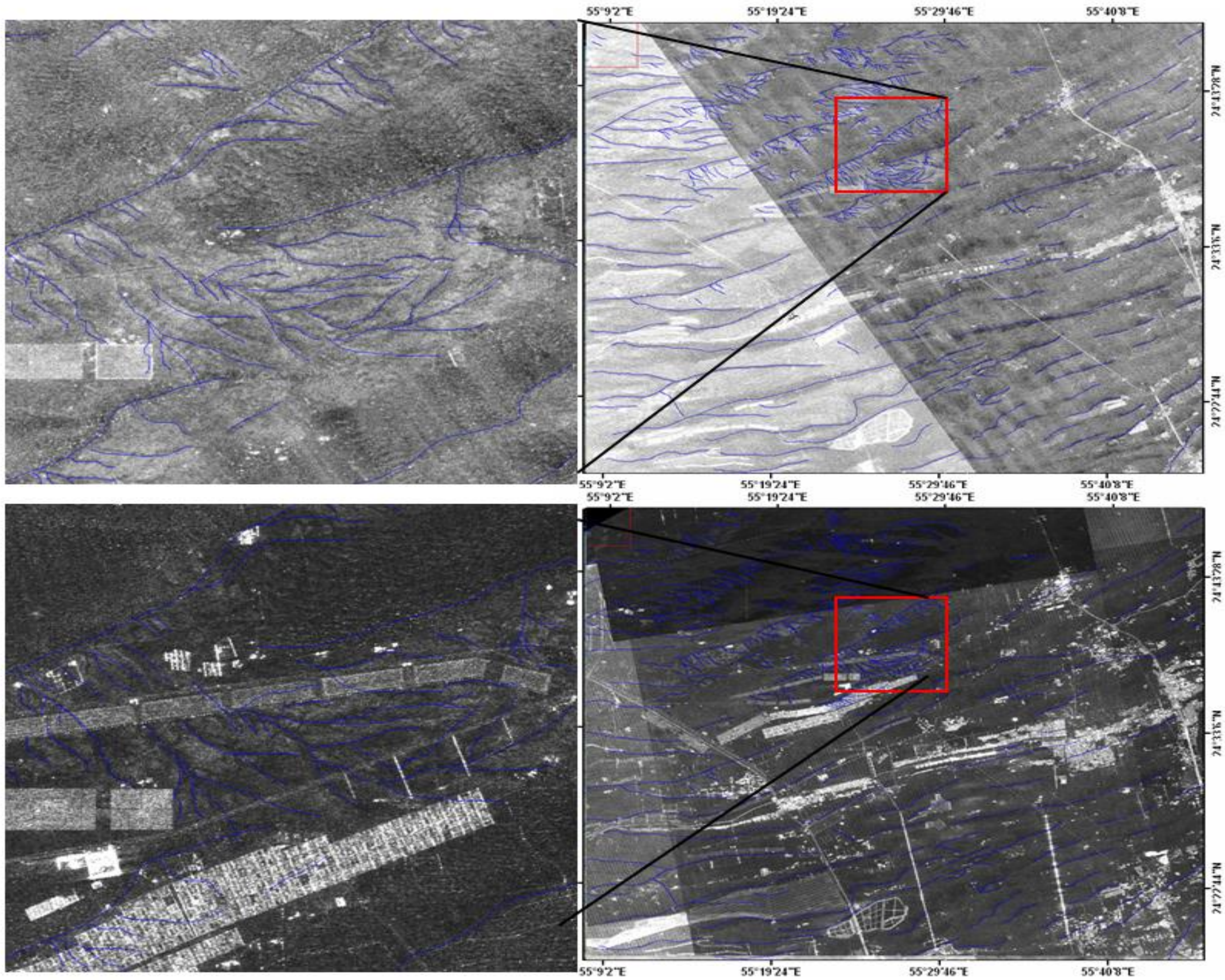

Fig. 3. HH polarization SIR-C images (up) and PALSAR images (down), showing the major paleodrainages flow underneath farms and share similar trends. They bring fine sediments from Oman Mountain (that formed from ultrabasic rocks) and form desert plains in the sand dune corridors. Thus, they have dark signature in optical and radar data.

While the small scale paleodrainages are difficult to discriminate using SRTM DEM due to their coarse spatial resolution, the SIR-C images PALSAR images of medium and fine spatial resolution allowed more detailed subsurface features underneath desert plain of sand dune corridors. The sand hills of the liner sand dunes does not allow for the active and passive remote sensing sensors to penetrate and imagine subsurface paleodrainages. So that, a possible connection between paleodrainages in the alluvial plain and plaeodrainages in the sand dune corridors could not be discriminated.

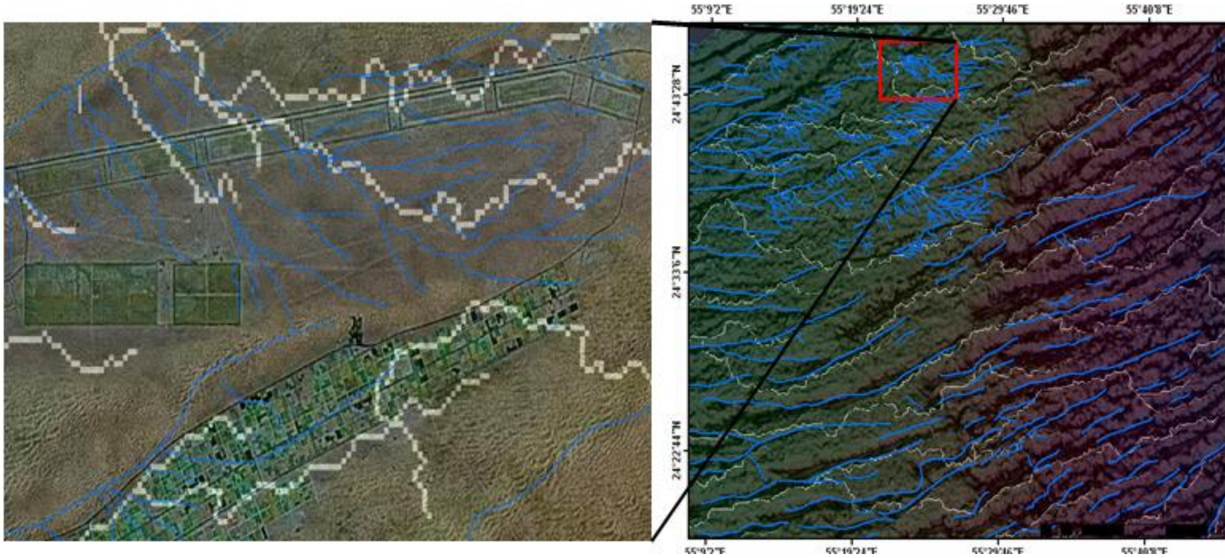

Fig. 4. Paleodrainges extracted from SAR data (blue lines) and those simulated automatically from STRM DEM (~90 m) using D8 algorithm (Jensen and Dominique, 1988), showing the spatial association between the locations and trends of paleodrainages and agricultural areas.

Similar to Hutchinson, (1996), this study proposes a possible regional flow (link) from the Oman Mountain to the Arabian Gulf (west) via paleodrainages underneath sand dunes and desert plains (sand dune corridors). The interpretation of various types of remote sensing data allows the mapping of large and intermediate paleodrainages underneath sand sheets of the sand dune corridors. For future work, it would be interesting to model soil moisture zones by using polarimetric covers dual HH/VV and HH/H of the SAR data and thermal band of LANDSAT images, and compare the results from that study with results from this study. Field observation and geophysical survey using Ground Penetration Radar (GPR) and Electrical Resistivity will conduct by the authors in Al Ashosh area (figure 4d) to determine the depth to the groundwater and groundwater quality.

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