Documenting Kara Caravan Trail Using Multi-Temporal Remote Sensing and GIS Techniques

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ABSTRACT

Remotely sensed aerial and satellite imagery are valuable tools for identification and mapping of historical sites. Application of Remote Sensing (RS) imagery and Geographic Information System (GIS) provide a more efficient way of identification, recording, and mapping historic sites associated linear features. In this research an integration of RS and GIS was used to identify and map the historical foot and camel trail in Jabal Kara, which forms part of the old caravan rout between Makkah and Taif in Saudi Arabia. It was constructed during the 4th century Hegira, and continued to be used till 50 years ago. Parts of this trail were destroyed during the construction of a high way in late 1950's. Our particular interest was documentation, and proposing a concept for rehabilitation. An aerial photo taken in 1953 was used with an IKONOS image of 2003 to identify and map this trail. The Aerial photo (scale of 1:48000) and IKONOS image were geo-referenced with ground control points (from a map). Highway and trail features were digitized using ArcView GIS. Trail length, width and slope were identified. Finally, a GIS database was build to be used for rehabilitation of this trail.

KEYWORDS: Historic Preservation, Archeological Documentation; Remote Sensing; Cultural & Historical Tourism; GIS; Aerial photography, Mapping. Hejaz; Saudi Arabia.

INTRODUCTION

For century's residents of Hejaz built several trails to connect the holy city of Makkah (300 m) above see level with Taif (2000 m). One of the most famous trials was Kara trail. Its name comes from the famous Kara Mountain that the trail climbs it to reach Taif. It is a historical foot and camel trail, which forms part of the old caravan rout between Makkah and Taif in Saudi Arabia. Kara Trail was constructed during the 4th century Hegira (10^{th} century G.), and continued to be used till 50 years ago. The governors of Makkah continue to pay efforts to improve and maintain Kara trail. See figure (1). Parts of this trail were destroyed during the construction of a highway in late 1950's. This research attempts to integrate of RS and GIS techniques to be used for identification and mapping Kara Trail from the top of the cliff to the beginning of Wadi Numan.

Figure (1): Section of Kara trail

Remotely sensed aerial and satellite imagery are valuable tool for the characterization of the archeological landscape (Kucukkaya A. 2004). They provides valuable data for mapping, environmental monitoring, and disaster management (Benz et al 2004).

The use of remote sensing, GIS, GPS and ground truthing provided a definite advantage over only ground data collection. Many of the statistics are quickly extracted from the GIS database for analysis (Laliberte et al 2001).

Remote sensing has seen improvements in spatial resolution (from 80m to sub-meter), spectral resolution (from three to 210 hyperspectral bands), temporal resolution (shorter visiting time and image on demand), and capability for stereo- imaging (3D mapping). All these advancements play a vital rule in detecting urban change such as changes in existence, shape, location, non-spatial characteristics and combinations of these. (Yagoub M. 2004)

Sokhi 1992 defined the historical site as a place where significant past events has occurred or an area containing property employed in, or monuments commemorating such events. He also defined the archaeological site as a place where material remains give evidence of past human life and activities. These remains can be movable and can lie above or below the ground. He suggested that Non- specialists often differentiate a historical site from an archaeological one by its visibility and state of preservation. Most of the structures and artifacts on archaeological property lie under the ground and must be excavated, whereas most of the structures and artifacts on a historical site lie above the ground. Accordingly, this defines our study site as historical site**.** However, considering the long history o the trail, it highly recommended to consider archeological excavation.

OBJECTIVES

Our particular interest was documenting of the trial route in Jabal Kara section. The study is intended to use a combination of aerial photograph with satellite imagery (IKONOS) to monitor and document Kara caravan Trail. The objectives of the study were:

- Detecting and identifying the location of the trail especially the lost parts

- Documenting the characteristics of the trail's parts, and
- Proposing a program for preservation and rehabilitation of the trail.

STUDY AREA & DATA

Study site

The study site is a mountain area as shown in figure (2), located to the north west of Taif city between (21° 20'N, 21° 23'N), (40° 10'E, 40° 16'E). Kara Trail, Al-Hada highway and a modern cable car project are exist in the study area.

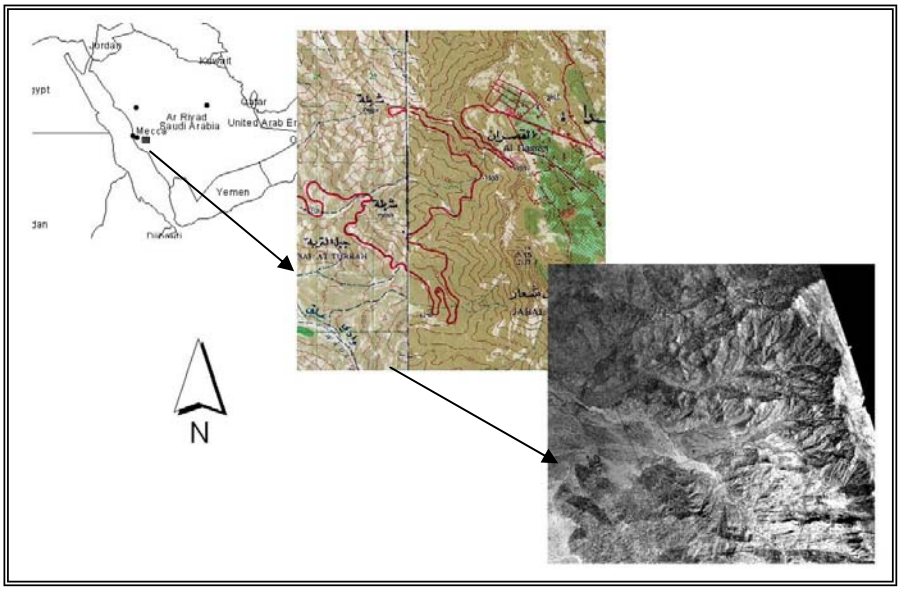

Figure (2): The study area

Data

Features and landscape patterns are recognized easier from the air than from the ground (Hinckley and Walker 1993).

This study requires large scale aerial photos, historic maps and documents, and high resolution GPS instruments for collecting

ground control points as recommended by (Boehler and Heinz 2002), (Ganas et al 2002), (Files 2003), (McCarthy and Stein 1999) (Gaughwin and Forghani 2000) and (Forghani and Gaughwin 2002). The selection of data used in this study was governed by both availability and accessibility.

The data used in this study included:

- Small scale aerial photograph (1: 48000) taken in 1953 with a metric camera of 153.64 mm focal length, using 24 cm film.
- IKONOS satellite image taken in 2003.
- Al Taif map of 1970 scale (1:50000).
- Wadi Al Numan map of 1970 scale (1:50000).

METHODOLOGY

Image processing and geo-referencing

The parts of interest of Al Taif and Wadi Al Numan maps were scanned at resolution of 600 dot per inch (dpi) and mosaiced together. The Aerial photo was scanned at a resolution of 1200 dpi. Although this created large image file of 110 megabytes, a high resolution was necessary for determining the trail features. The mosaicked image was geo-referenced to Universal Transverse Mercator (UTM) projection using international spheroid of 1909 and Ain Al Abd 1970 datum utilizing the software program ERDAS Imagine® 8.5, using a second order polynomial geo-referencing operation. The intersection points of a coordinates grid superimposed over the original map were used as Ground Control Points (GCP).

Once mosaicked image had been rectified, IKONOS image was geo-referenced using the mosaicked image as a baseline. Fifteen identical points along the highway were chosen on both images and used for the geo-referencing. The GCP were chosen along the highway since it is the only feature that is will recognized in both images. The average Root Mean Square (RMS) error was 3.56, with a pixel size of 1 m, resulting in a ground accuracy of 3.56 m. This is close to the horizontal accuracy (RMS) of 3m obtained by Zhou and Li (2000) with simulated IKONOS data. Figure (3) shows IKONOS image with an overlay of the control points.

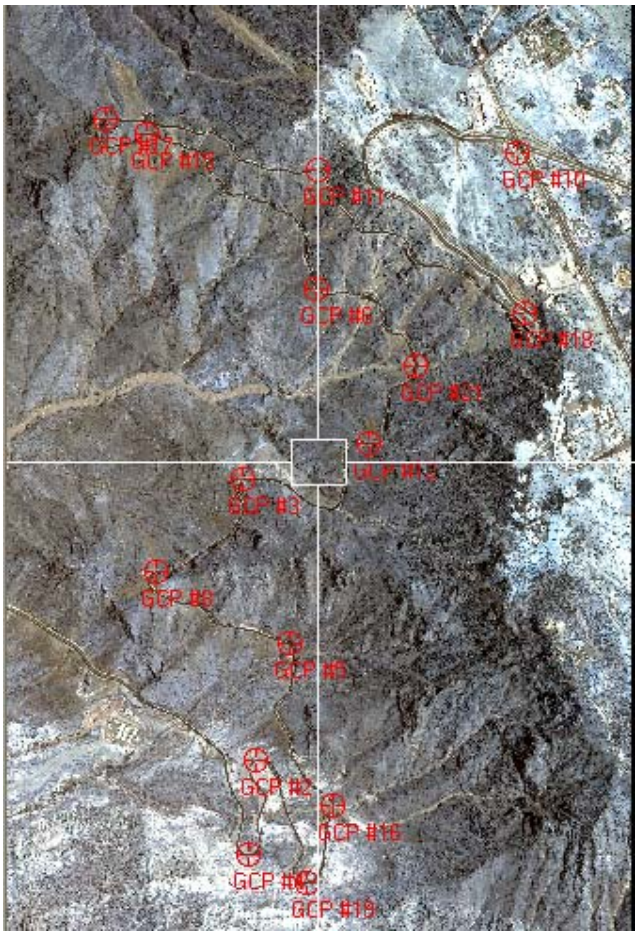

Figure (3) IKONOS image with GCP

The rectified mosaicked and IKONOS images were used as a baseline to geo-referencing the aerial photo. The geo-referencing of the Aerial photo was very difficult task. The area of interest had a steeper topography, the highway was not on the photo and the overlap with IKONOS image is about 25% of the photo size. On the other hand, there were a few objects which were recognized on both the mosaicked and aerial photos. Fourteen GCPs were selected; ten of them were concentrated in the overlapped area between IKONOS image and Aerial photo since it is the area of interest. The geo-referenced photo was resampled to 1 m pixel

size and the average Root Mean Square (RMS) error for the ground accuracy was 57.21 m.

Digitizing of Trail features

Visual interpretation factors such as color, size and shape, were extensively used in identifying trail features from aerial photo and IKONOS image. Visual interpretation of imagery by skilled interpreters in appropriate operational contexts is often the most accurate technique (Yagoub 2004) after (Deane et al. 1989). Forghani (2000) suggested that, GIS data and remote sensing imagery were applied to build a database.

The Trail parts were digitized on-screen from both aerial photo and IKONOS image, using the software program ArcView 3.2. The locations of the trail from IKONOS image were adopted, and lost parts which identified from aerial photo, were digitized and shifted to match the adopted locations. The length and width of the trail parts were calculated. Later, mosaicked map was used to calculate the slope of the trail parts. In addition to the trail features, the highway and drainage system were digitized.

RESULTS & DISCUSSION

The first objective of this study was identifying the location of the trail parts as a primary step for preservation. The trail extends from Makkah to Taif for a distance over 80 km which is too long to be covered in the study. We concentrated on the last 4 km of the trail in Jabal Kara section of the trial. Figure (4) shows the trail parts, the highway and the drainage system in the area of interest. The trail parts are classified to existence, lost and projected. The projected parts lay outside the study area and they are found in the aerial photo, this part still to be verified on ground.

The lost parts are found at the intersection of the trail with the highway and the main drainage line. The alignment of the lost parts (due to the construction of the highway) was identified using the 1953 aerial photo. The parts lost due to the drainage are not found, it is possible that it was lost before 1953 or never been constructed as a stone paved trial. The total length of each of the three categories is summarized in table (1).

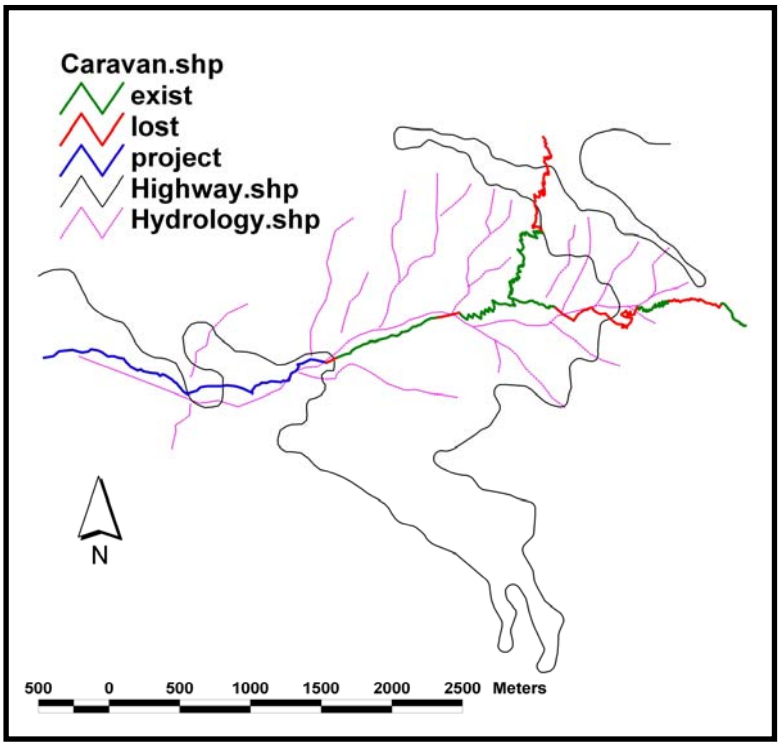

Figure (4): The trail location

Table (1): the total length of trail parts

status	Total length (m)
exist	3872.6890
lost	2956.3840
projected	7628.2990

The trail was used for both foot and camel caravan from Makkah to the point called Al-Rokbah (Knee) at the beginning of the steeper slope area. At this stage it branch into two trails; one for pedestrian and the other for camels, as shown in figure (5). The characteristics of the trail parts like width, length and slope were calculated using ArcView software and summarized in table (2).

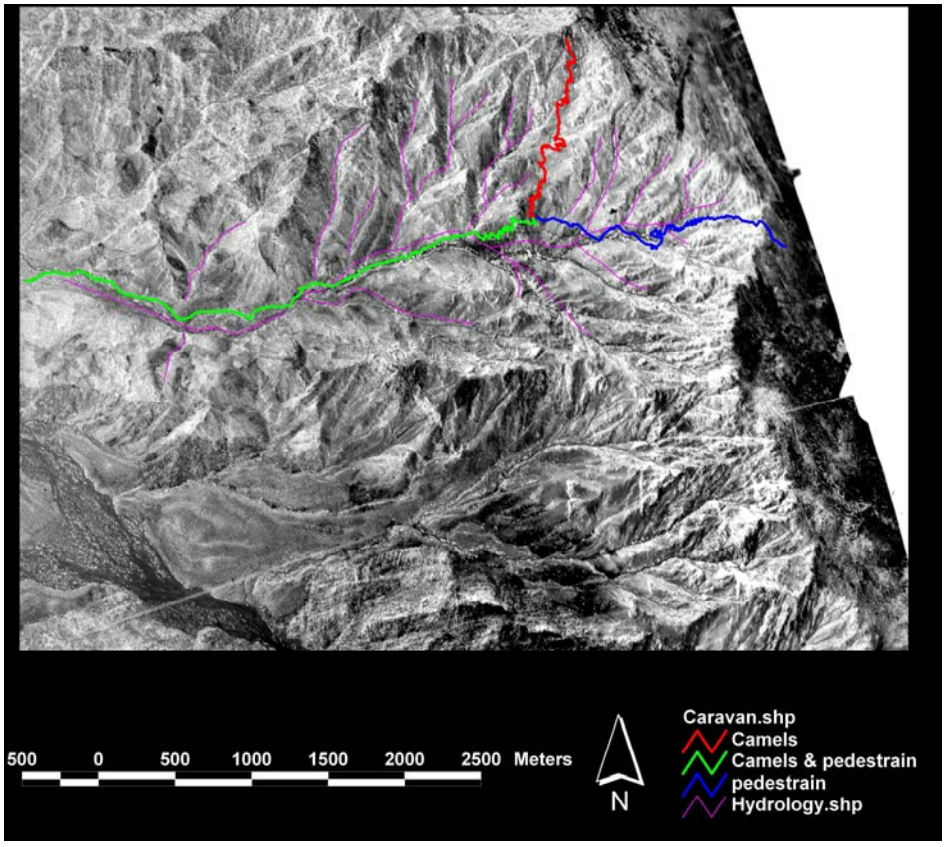

Figure (5): The trail usage overlaid onto the georeferenced photo

Table (2): The characteristics of the trail parts

USE	**Total length**	**Ave. slope %**	**Ave. slope Deg**
Camels	2324.1230	39.8177	21.6650
Camels & Pedestrian	9457.4360	17.8810	9.9175
Pedestrian	2675.8130	30.4622	16.4910

The width of the trail at some points was measured both on screen and in the field. The results are shown in table (3), from which it is clear that the use of GIS can save the efforts and time and it gives the same results as the field measurements.

Table (3): Comparison of trail width measurements taken in the field and from IKONOS image on the computer screen.

point	trail width Field (m)	trail width On-screen (m)
1	3.1	3.28
2	4	3.71
3	5.2	5.18
4	6	5.67
5	6	5.43
6	2.5	3.28
7	4.5	4.35

Rehabilitation Concept

In such a case of valuable historical and cultural site, it is important to consider the potential for cultural and historical tourism activities. Kara trail represent part of the Hejaz heritage, introducing such valuable side of local culture to the new generation is ever important. The concept of rehabilitation can take the basic concept of caravan history and famous event such as the prophet journey to Taif, which took similar path. Another ingredient of rehabilitation theme is the rich record of this trial in explorer's stories and records.

From a physical point of view, a comprehensive restoration program is urgently needed to restore deteriorated sections, and to reconstruct the missing parts. However, reconstructing the missing parts can take more metaphorical representation of the trial direction rather than physical reconstruction. For example, marking the missing section over the existing road, or marking its route by using light sources, possibly including fiber optic lighting and laser beams. The thematic side can represent the prophet journey along the pedestrian section of the trial, telling the prophet life story (Al-Serh Al-Nabweyah). Records of explorer's and ancient travelers can be told along the camels section of the trial.

The theme of a tourism program, should introduce visitors to caravan culture, and the importance of this trail for pilgrimages visiting Makkah. A visitor center can be developed in the top of the mountain including small theater and interpretive exhibition halls telling the story of caravan trips and pilgrimages experiences. Restoring important features such as water pools and rest houses will bring such elements to live. This can include organizing camel and hiking trips up and down the trial. Such a rehabilitated site can attract school visits and travelers along the heavily used road between Makkah and Taif.

CONCLUSION

The ground resolution is an important determinant factor for feature detection. It was clear that the use of large scale aerial photo or high resolution satellite images is essential, especially when there is a low contrast between features and background.
The use of remote sensing and GIS to build the database provided more advantages over only ground data collection. Many of the statistics are quickly extracted from the GIS database for analysis. Furthermore, the ability to overlay many features, measure distances, and calculate other parameters is helped in data analysis and consequently documenting this historical trial. On the other hand, Geo-referencing small scale aerial photo for mountain can be a very difficult task without the use of artificial targets as GCP.
The proposed Rehabilitation concept needs an urgent detailed program in order to maintain this valuable site for the next generation. The site has a grate potential for historical and cultural tourism activities.

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