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Cover photograph of a joyful family stroll on a UAE beach
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Geographic Information System (GIS) Application for Camels: The Case of Al Ain, United Arab Emirates (UAE)[1]

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Since the 1980s the United Arab Emirates (UAE) has witnessed rapid socio-economic transformation, which has affected many aspects of land and life that are of interest to geographers, including the spatial distribution of camels. This study utilized Geographic Information System (GIS) and spatial analysis to understand the changing distribution of camels. The research revealed that camels in the UAE are now clustered near racetracks and not near traditional magnets such as sources of water and grazing areas. Such clustering is unique to the UAE and is unknown in the other countries of the Middle East and North Africa. The clustering is due to social and economic factors related to racing. The chief social factor is the high prestige associated with winning a camel race, and the main economic factor is the high value of winnings from camel racing (prizes may reach US$ 3 million). The results of this study have helped to change peoples' perceptions about the capabilities and potential use of GIS for issues relating to camels. Countries that have large populations of camels and other domestic animals may find it appropriate to apply the GIS analysis used in this study.

Key Words: Camels, GIS, UAE

Depuis les années 1980, les Émirats Arabes Unis (ÉAU) ont connu de rapides transformations socio-économiques qui ont affecté de nombreux aspects de la vie et de l'espace, dont la distribution spatiale des dromadaires. Ce travail utilise les Systèmes d'Information Géographique (SIG) et l'analyse spatiale pour comprendre les mutations dans la distribution des dromadaires. La recherche a montré que les dromadaires des ÉAU sont actuellement concentrés autour de champs de courses et non plus à proximité des pôles traditionnels qu'étaient les points d'eau et les parcours de pâturage. Cette concentration, particulière aux ÉAU, est inconnue dans les autres pays du Proche-Orient et d'Afrique du Nord. Elle est la conséquence de facteurs sociaux et économiques en relation avec les courses. Le principal facteur social est le prestige associé à la victoire d'une course, tandis que le principal facteur économique est la hauteur des gains escomptés, les prix pouvant atteindre trois millions de Dollars US. Les résultats de cette recherche ont contribué à modifier la perception des possibilités et de l'utilisation potentielle des SIG pour des travaux sur les dromadaires. Des pays avec une importante population de dromadaires et autres animaux domestiques pourraient appliquer les analyses des SIG présentées dans cette étude.

Mots clés : Dromadaires, SIG, ÉAU

Geographic Information Systems (GIS) technology is becoming relatively inexpensive. Digital spatial data are increasingly available, the costs of hardware and software are continuously falling, and the user interfaces are improving. These advantages have opened new areas for the application of GIS,

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including the study of livestock and wild animals. GIS has, for example, been used in studies of tigers in the Indian subcontinent and of elephants in Kenya (ESRI 2002). This study deals with the application of GIS to problems related to camels in Al Ain, UAE.

The spread of camels in some areas may be due to the economic benefits. The camel has long been the desert dweller's primary source of transport, milk, meat, shade, and wool (Bulliet 1975; Faulk 1976; Fowler 1950; Lawrence 1935; Wilson 1984). In many parts of Africa and Asia today camels still pull ploughs and turn water wheels and grinding wheels (Zayed, Kadri, and Shurikha 1991). Currently the majority of people in the study area, and in the UAE in general, do not use camels as a means of transport or for carrying goods (Crocetti 2000). This may be due to the advances in the car industry, so that four-wheel-drive cars are capable of defeating the desert.

Large populations of camels in some countries such as Somalia, Sudan, and Mauritania are still managed by nomadic pastoralists, responding to changing patterns of water and grazing areas. A study carried out by Wardeh (1989) in Mauritania showed that most camel herders practice seasonal migration with their camels through identified grazing areas according to traditional tribal rights and the availability of vegetation. However, around 70% of camels in the UAE area are now stabled in permanent locations.

The government of the UAE has strongly encouraged camel racing as a public sport, especially since the formation of the Camel Race Federation in 1992. Camel racing is now meticulously managed, with attention to such issues as racetrack design, scheduling, camel training, diet, and health, and racing regulations. There are now more than 15 large racetracks (of more than 10 km in length) across the UAE, situated in luxurious and spacious stadiums where audiences may enjoy one of the most popular pastimes in the UAE (Cullen 1999).

The majority of studies about camels in the UAE have focused on biology, history, and culture (Alami 1998). It is believed that no study has been carried out in the UAE dealing with the *geographical* aspects of camels. This is not unexpected because, worldwide, there are comparatively few studies dealing with animal distribution and zoological mapping (DeMers 1997). One problem with mapping animals is that they regularly change their locations. Since this is no longer typical of camels in the UAE, GIS provides some unique tools for understanding and even improving upon the new realities of camel husbandry in the country.

There are numerous issues in camel husbandry and management for which GIS can be used, including the use of buffering, as a GIS tool, for point-in-polygon analysis and to check the proximity of stables to roads, optimum routes and travelling time to racetracks, access to veterinary clinics, and proximity to water-filling stations. GIS integrated with GPS can also be used for checking the patterns of movement of camels and for monitoring racing, using location-based services (LBS). GIS spatial analysis was used in this study to visualize accurately how camel distributions have changed.

Research Problem, Objective, and Methodology

Information about camel racetracks in the UAE is becoming very important for competitors in this public sport, for camel breeders, and for officials. There is no proper spatial database for Al Ain showing locations of camel stables in relation to racetracks, main roads, veterinary clinics, and fodder farms. Delivery companies that work in various fields related to camels (e.g., water, fodder, veterinary medicine, emergency services) are in need of digital data through which they can optimize their services and increase their profits. For example, the companies are interested in knowing the locations of remote racetracks so they can target them and maximize their profits (travelling longer

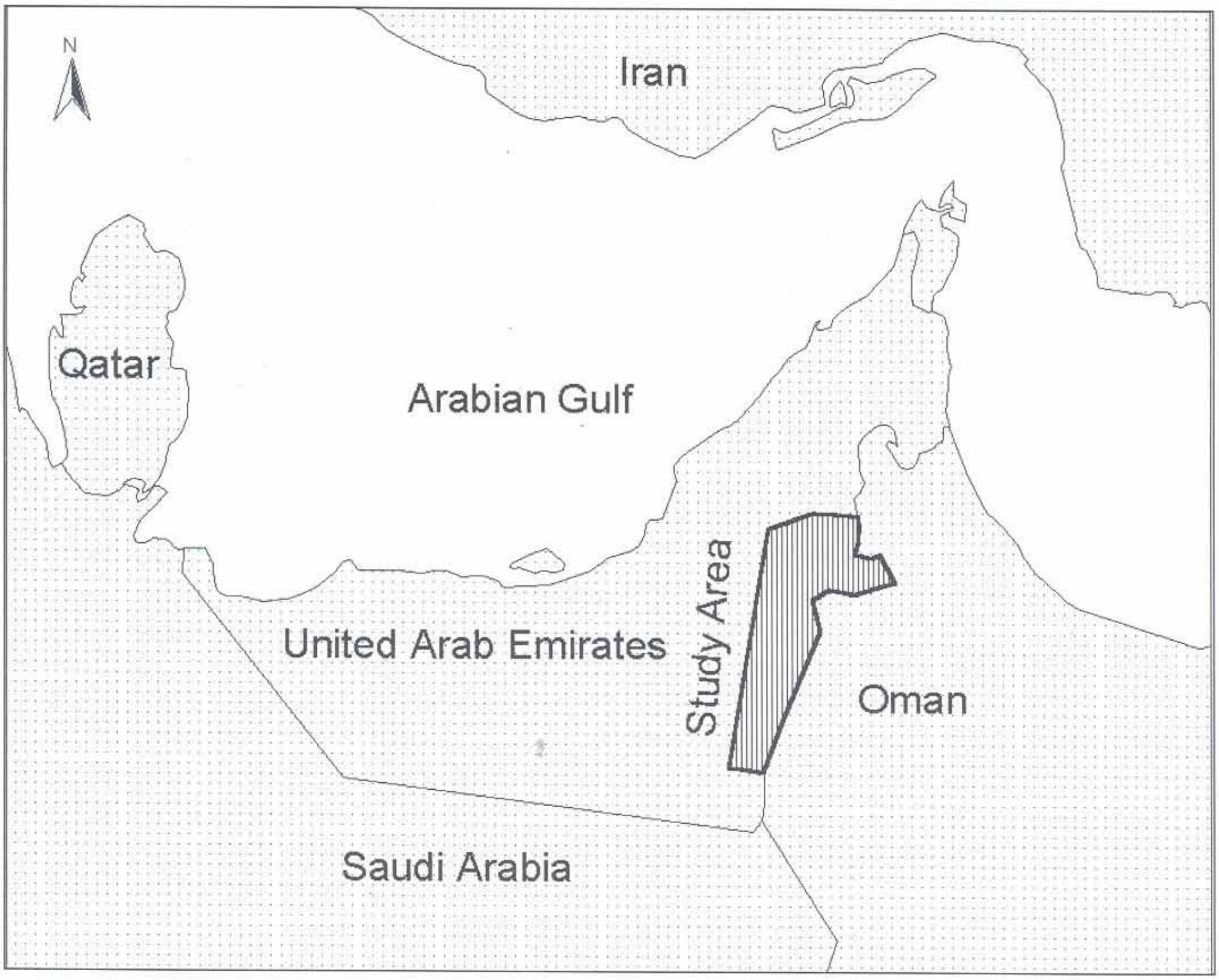


FIGURE 1
Location of the study area. Note: The map shows the *approximate* boundaries.

distances means more money for the companies). At the same time, town planners in Al Ain would like to see implementation of their rules requiring the location of racetracks 10 km outside the city. GIS databases and spatial analysis may help address the interests and needs of these diverse groups.

The objective of this study was to explore the possible use of GIS analysis in investigating the spatial distribution of camels (stables) with respect to the distribution of facilities such as fodder farms, racetracks, water-filling stations, veterinary clinics, and roads. It is hoped that the research findings will prove to be useful to the interests of many parties concerned with camels in the UAE and abroad.

A pilot study was conducted in the eastern region of UAE (Al Ain) (see Figure 1) to investigate the spatial relationship between camel stables, on the one hand, and sources of water and food for the animals, on the other. The region was selected because of its high population of camels (84 % of camels in the UAE are in this region; Abdalla 1988), the availability of some data, and accessibility to the researcher. The region is located approximately between 23° 03′ and 24° 40′ north; 55° 05′ and 55° 53′ east. The climate of the region is hot desert, with a mean annual rainfall of only about 96.4 mm. The average temperature during summer is about 35° Celsius; and during winter, about 18 ° Celsius.

The steps followed in building this GIS database included data collection, digitization of geographic data, creating a topology, checking feature accuracy, and transforming data to a real-world coordinates system; then preparing the attribute database and linking

TABLE 1
Attributes of camel facilities

Geographic feature	Attribute
Fodder farm	Name of owner, area, cultivated area, type of soil, average elevation, number of wells, type of irrigation (dripping, sprinkling), type of fertilizers (potassium nitrate, organic, sulphate), type of fodder (alfalfa, Rhodes), production (ton), productivity/m^2
Racetrack	Name, date of establishment, area, number of workers, percentage of greenery, capacity for spectators, VIP hall, helicopter landing area, facilities (veterinary clinic, restaurant, toilets, mosque, shop, public telephone, number of large screen displays, parking area)
Road	Name, length, type, direction
Stable	Name of owner, area, number of camels, main use of camels (milk, meat, race), number of workers, facilities (room for workers, shelter for camels, store for fodder, water tank, car allocated to the stable)
Valley	Name, width, type of vegetation
Veterinary clinic	Name, date of establishment, number of doctors and workers, type of services (surgery, provides medicine only), number of cases treated in each year, number of emergency cars (ambulances)
Water-filling station	Name, district, capacity, average pH of water

geographic data with attribute data. The hardware used in this study included a PC Pentium IV (RAM 128 MB, HD 15 GB), an HP DeskJet 1220C colour printer, and a Genius Vivid III scanner. The software used in preparation and analysis of the data included Adobe Photoshop, ArcView 3.2 with Network Analyst, and MS Access. Spatial analysis was used as the main method of quantifying racetrack distribution with respect to other facilities and features, such as roads and the airport.

Data related to the locations of roads and fodder farms were collected from Al Ain Municipality. Attribute data about the number of wells, farms, and veterinary services were collected from the Al Ain Department of Agriculture and Animal Resources. Information about racetracks and potential camel stable sites, the number of camels in each location, the facilities available, and other features were gathered from the Camel Race Federation and a field survey. A Magellan Global Positioning System (GPS) receiver was used to locate camel stables. A summary of the attributes included in the GIS database is shown in Table 1. Al Ain Landsat TM satellite image of 2000 was obtained from the remote sensing centre at the UAE University; the image was used to delineate the city boundaries.

GIS Analysis for Camels

GIS analysis was exploited throughout the study to assist in understanding the distribution of camel stables with respect to other facilities, such as fodder farms, racetracks, veterinary clinics, water-filling stations, and roads. The spatial analysis used in this study included proximity analysis, spatial statistics, and network analysis. To support the spatial analysis, a self-administered questionnaire was used.

Proximity Analysis

In GIS it is possible to run different scenarios with different buffers. In this study, a buffer zone of 5 km was created around fodder farms, racetracks, veterinary clinics, and water-filling stations. The 5 km was chosen as an appropriate distance, not too near and not too far from the facility. This buffer zone was

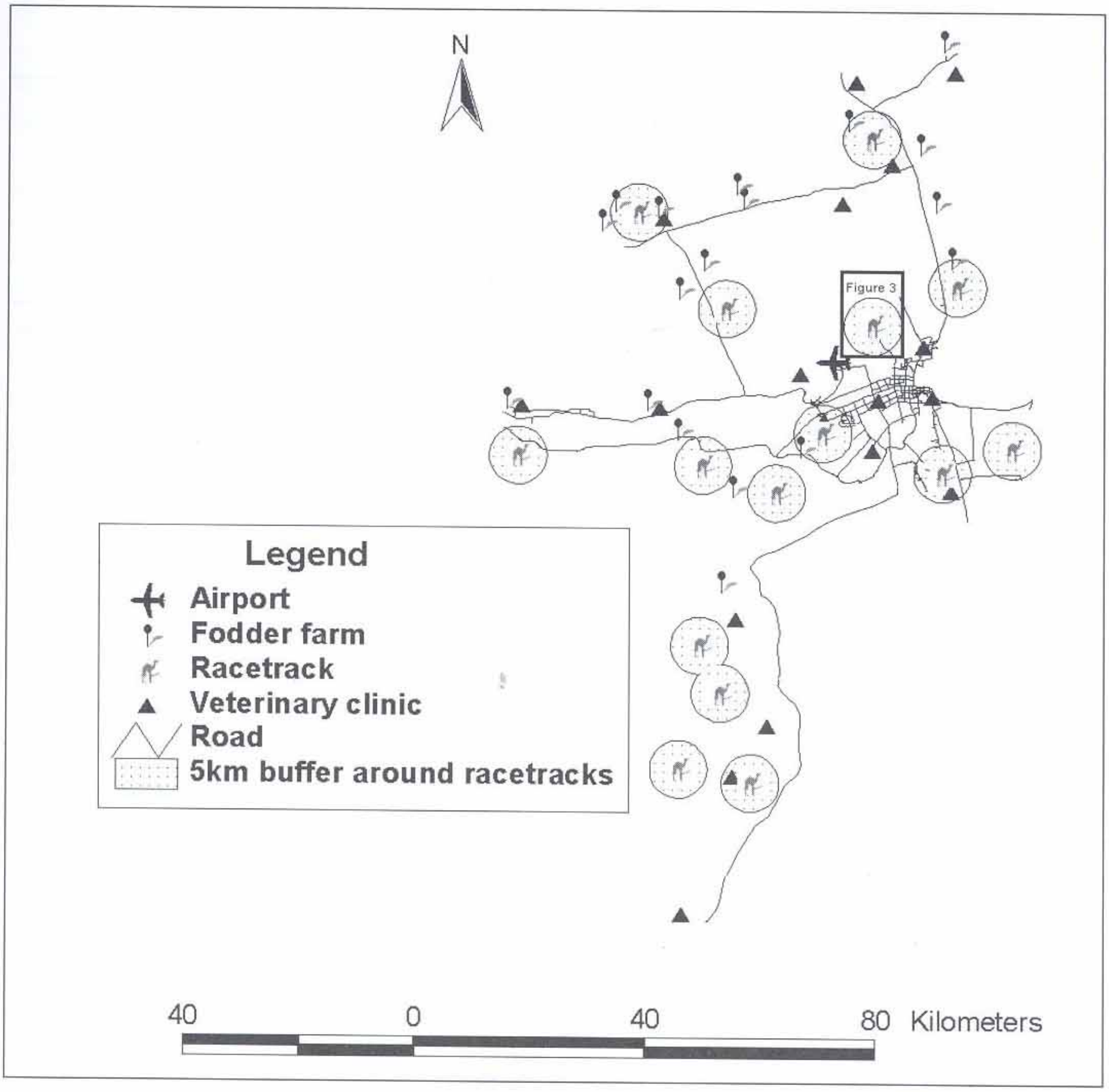


FIGURE 2
Geographical features related to camels and buffer around racetracks.
Note: To avoid map congestion not all features and buffers are shown.

used to quantify camel density around each facility. Eighteen percent of the camel stables (total 600) were found within the buffer zone of 5 km around fodder farms, 98 % around racetracks, 9 % around veterinary clinics, and 24 % around water-filling stations. It has to be noted that, in some situations, buffer zones overlapped; the percentages, therefore, may not add up to 100. A spatial join to connect the stables (points) to the 5-km buffer zones (polygons) was used to calculate the stable density within each zone (polygon). A principal finding is, thus, that the majority (98 %) of stables are clustered near racetracks and not near fodder farms, veterinary clinics, or water-filling stations. Therefore, racetracks can be considered the focal point for camel stables; hence, any other facilities can be referenced to them.

Another buffer zone of 5 km was created around racetracks, to check the percentage of facilities within the buffer. Only 4 out of 18 (22%) fodder farms were found to be within the 5-km buffer zone around racetracks (see

TABLE 2
Buffers with different radii around roads and percentage of facilities within each buffer zone*

Buffer (km)	% Fodder farms	% Racetracks	% Veterinary clinics	% Water-filling stations
2	22	13	50	60
5	78	67	83	90
10	100	80	100	100

* Total number of fodder farms is 18, of racetracks is 15, of veterinary clinics is 18, and of water-filling stations is 20.

Figure 2). This suggests that there are good opportunities for fodder-delivery companies because as the distance increases, the charges also increase. Within this buffer zone, only four veterinary clinics were found—22 % of all veterinary clinics. This result indicates that the majority of veterinary clinics (78 %) are not in suitable locations to provide quick services to camels. This is natural because as the city grew, animal facilities had to be relocated. Only 3 out of 20 water-filling stations (15%) were found within the buffer zone of 5 km around racetracks. The low percentage of water-filling stations near racetracks is because the majority of the stations were originally designed to serve residential areas and not camels. Although some camel owners dig wells near their stables, city authorities in the city have made a rule forbidding such activities. The main objective of this rule is to conserve groundwater. The location of the majority (75 %) of water-filling stations away from the camel stables is to the advantage of those who work in the water industry. Hundreds of water tankers with different capacities (500–5 000 gallons) were observed everyday around water-filling stations serving residential areas as well as camel stables. Various parties have benefited from this business, such as companies selling tankers, tanker owners, tanker drivers (job creation), and camel owners.

Planning rules require the location of racetracks outside the city boundaries. The objective of these rules is to avoid any environmental hazards caused by camels (e.g., accidents, odour, spread of disease). The city boundaries were delineated as polygons on the Al Ain Landsat TM satellite image of 2000. In point-in-polygon analysis, none of the racetracks (points) were found within the city boundaries (polygons). Because the airport represents a source of noise for the camels, and the camels' odour is a concern for the airport, planning rules require racetracks to be no closer than 10 km from the airport. A GIS buffer of 10 km around the airport showed that only 7 % of the racetracks are within this zone. From this analysis, it is apparent that planning rules concerning the location of racetracks outside the city boundaries and away from airport by 10 km have been implemented.

To check the proximity of racetracks and camel facilities to the main roads in the area, GIS buffers with different radii (2, 5, and 10 km) were made around roads (see Table 2). The buffers are useful in analyzing operations such as emergency services, the movement of mobile veterinary clinics, and the delivery of water and fodder. The analysis established a 2-km buffer zone around roads as a "danger zone" because sometimes camels wander along roads and cause fatal accidents. The 5-km buffer is considered appropriate for the delivery of services and the 10-km buffer is considered suitable for the location of camels away from roads (minimizing the probability of accidents). Only 22 % of fodder farms were found within the 2-km buffer zone around roads, the recommended distance of fodder farms from roads (see Table 2). Two race-

tracks out of 15 (13 %) were found to be within the 2-km buffer zone (Table 2). These two racetracks were highlighted as hotspots in need of special precautions and arrangements, such as fencing along roads or posting of road signs showing camels. Notably, nine veterinary clinics (50 % of the total) and 60 % of water-filling stations were found to be within the 2-km buffer zone (see Table 2). The inconsistency between the proportion of racetracks (13 %) and the proportion of veterinary clinics (50 %) and water-filling stations (60 %) inside the 2-km buffer zone may be due to the way Al Ain has developed. Initially, veterinary clinics were established near racetracks, such as the abandoned one near Al Ain Hospital. With urban expansion, the racetracks were shifted to the city's outskirts, while veterinary clinics remained where they were. With respect to water-filling stations, as was mentioned earlier, the stations were originally designed to serve residential areas; therefore, their location near roads is to be expected. Seventy-eight percent of fodder farms, 67 % of racetracks, 83 % of veterinary clinics, and 90 % of water-filling stations were found within the buffer zone of 5 km around roads (see Table 2). The results for both the 5-km and the 10-km buffer zones around roads revealed that more fodder farms, veterinary clinics, and water-filling stations were located near roads than racetracks (see Table 2). This result indicates that racetracks are located far from roads; so accidents will be minimized. On the other hand, it is easier to provide fodder, clinical services, and water by transporting them than transporting camels to trace tracks, even if the location of camels is far from roads. The advantage of GIS is that once the database is built, different users can change the buffer distance (provides more flexibility) and results can be obtained within minutes.

The historical clustering of camels near oases and valleys for water and grazing is changing nowadays in the UAE, in a remarkable paradigm shift. This shift may be due to the overall scarcity of water and vegetation cover in the region in comparison to the past. To check the validity of this assumption, a 10-km buffer zone was made around valleys in the region. Ten kilometres was chosen to increase the probability of finding racetracks within the zone. A spatial join was made between the zone (polygon feature) and racetracks (point features). Only six racetracks (40 %) were found within the zone. The result indicates that valleys are no longer focal points for camels. In addition to that, valleys are now falling under the continuous urban expansion of Al Ain. The expansion of the city towards the valleys has compelled the Al Ain Department of Agriculture and Animal Resources to increase fodder farms (Al Ain Department of Agriculture and Animal Resources 1999).

Spatial Statistics (Distribution of Camels)

GPS locations for stables were organized in the form of a table containing each stable's label and coordinates (X, Y). The file was loaded as an event theme in ArcView. The mean centre of the stables was found to be at 363475, 689313 (m) and the standard deviation was 971, 422 (m). The large standard deviation in the x-axis indicated that the stables follow, to a large extent, a linear pattern along the x-axis (see Figure 3). A script developed by the Environmental Systems Research Institute (ESRI) (see http://arcscripts.esri.com/details.asp?dbid=10642) was used to perform spatial nearest-neighbour analysis. The analysis calculated the nearest neighbour index (NNI) value and determined how many stables were accounted for in the analysis. NNI values reveal how clustered or dispersed stables are. An NNI value of zero indicates an intensely clustered pattern, while an NNI value of 1 indicates a random distribution, and an NNI value of 2 (or higher) indicates a strongly dispersed or organized pattern (Chou 1997). The NNI value was found equal to 1.01, with the number of stables equal to 97. This implied that stables were randomly distributed (see Figure 3). Linear distances between sta-

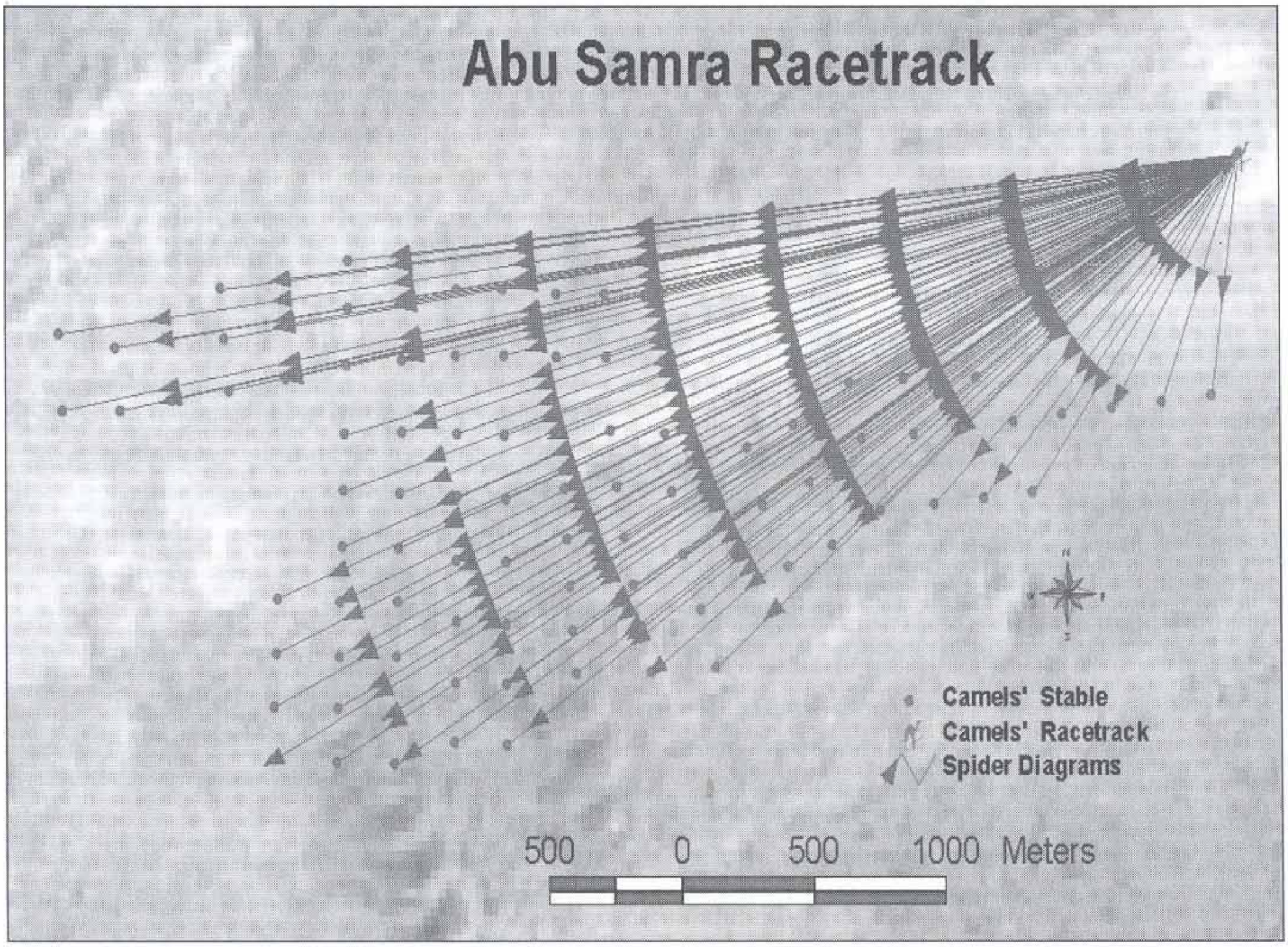


FIGURE 3
Spider diagram showing the clustering of stables near Abu Samra racetrack and the distance between the racetrack and each stable.
Note: Landsat TM satellite image of 2000 was used as a background (note the location of stables in the desert).

bles and racetracks were calculated using spider analysis (see Figure 3). The statistical summary indicated that the minimum distance was 746 m, the maximum was 4 514 m, and the mean was 2 872 m. The result showed closeness (concentration) of camels near racetracks (see Figure 3). The statistical analysis was done inside ArcView, eliminating the need for and cost of buying a specialized statistical package and allowing the analysis to be performed under one window, rather than by flipping between different windows.

Network Analysis

Network analysis was used to find the closest facilities (water-filling stations, veterinary clinics, and fodder farms) to racetracks and to find the optimum routes to and from the facilities. Application of network analysis was found to be difficult, because not all camel stables were near roads, as hospitals and schools were. Since the majority of camels were clustered around racetracks, the locations of racetracks were used as focal points. All racetracks and facilities near roads were then snapped to the main roads and calculation of the distance matrix and travel time between the racetracks and the facilities was performed (see Table 3). Time zone maps showing distances and directions (cartograms) were generated. To save time for novice users, programs were developed in Avenue allowing a user to select a racetrack and services needed, with the system automatically colour-coding the nearest facility.

TABLE 3
Travel time (in minutes) matrix between racetracks and veterinary clinics

Clinic	Race track			
	Al-Jeeb	Qashaba	Alsad	Al-Maqam
Al-Yahar	35	25	15	*10*
Sewaihan	15	25	16	32
Al-Khazna	78	65	38	45
Al-Hayer	*12*	15	20	37

Note: Bold numbers indicate shortest travel time; for example, the nearest clinic to Al-Jeeb racetrack is Al-Hayer (12 minutes) and the nearest clinic to Al-Maqam racetrack is Al-Yahar (10 minutes).

TABLE 4
The strongest reason for breeding camels (number of respondents is 70)

Reason	% Respondents
Meat production	19
Milk production	18
Leather production	9
Racing	41
Heritage	13
Total	100

Questionnaire

To enhance and strengthen the spatial analysis, a self-administered questionnaire was prepared and distributed to 70 camel owners (respondents). The questionnaire was prepared in Arabic in order to be understood by local owners. The questionnaire included questions about such things as strongest reason for breeding camels (economy, heritage, social), purpose for breeding camels (for milk, meat, or race), suitable location for stable (near water, fodder farm, veterinary clinic, or racetrack), frequency of participation in racing, volume of water and weight of fodder needed weekly for camels, and facilities available at stable. Results from the questionnaire showed a high tendency of owners to breed camels for the sake of racing and its perceived rewards (see Table 4). Results also showed that 68 % of the respondents participated in camel racing mainly to win cash prizes, while 32 % participated mainly to enhance their reputations. The majority of the respondents (76 %) had participated in more than three camel races and won prizes ranging between 600 000 and one million Dirhams. Fifty-one percent of the respondents preferred their camels to be located near racetracks; this was followed by near water sources (20 %), near fodder farms (15 %), and near veterinary clinics (14 %). This may be interpreted as reflecting the continuous need for training camels in racing, and the availability of tankers for bringing water, trucks for delivering fodder, and movable veterinary clinics.

It was found that there was a socio-economic rationale for the clustering of camels near racetracks. Camel owners compete in racing for economic and social benefits (Alnobi 1992). A total cash prize of US$3 million is allocated annually to the final races. In addition, a total of 102 cars, and smaller cash prizes ranging between US$1 300 and $4 000, are offered to winners in the semi-final races (Camel Race Federation 2002). The large sum of prize money is an incentive for camel owners to build their stables near racetracks, so that they have more time for training. Although camel owners spend money to bring water and fodder by truck from remote areas, the cost of water and fodder constitutes a small fraction of what their prizes could be. These considerations explain why the clustering of stables around racetracks is becoming a geographical phenomenon.

Conclusion

The clustering of camels near oases and valleys for water and grazing is no longer a spatial paradigm in the UAE. This study utilized GIS technology and spatial analysis to identify a significant paradigm shift. Spatial analysis functions, including proximity, spatial statistics, and network analysis, were used extensively throughout the study to understand the spatial distribution of camels. Camels were found clustered mainly near racetracks, due to the perceived social and economic benefits of racing.

The study was faced with numerous problems, particularly in the identification of stables, owing to their location among high sand dunes. However, using GIS for camel analysis proved very satisfactory, with benefits accruing from the ease of data manipulation, analysis, and display. An important lesson learned from this exercise is that spatial analysis can be strengthened by a questionnaire or a survey to give it a social dimension. It is also clear that to convince the public of the viability of GIS, one has to produce something tangible—preferably hard-copy maps—beforehand.

The major benefit of the approach employed in this study is in the ability of a GIS database to deal with different scenarios, such as generation of buffers around racetracks and roads and exploring the spatial relationships between stables, on the one hand, and fodder farms, clinics, and water-filling stations, on the other. Various people involved in camel activities, including camel owners, veterinary doctors, and drivers of vehicles supplying water, fodder, and emergency services have already made use of the study. City planners have used the GIS system to identify camel stables inside urban areas to check the legality of the stables. Planners have also used the system to identify promptly which veterinary clinics should be shifted outside the urban areas. Camel management officers have been able, through querying of the database, to identify racetracks and stables not adhering to the standards and specifications set by the authority. Delivery companies working in the field of camels have used the system to optimize their services. For greater benefit to the local community, Arabic versions of maps have been prepared. The study has shown that GIS applications are open to the imagination of the user and yield many benefits.

Future work will focus on tracking the movements of racing camels by deploying special GPS tracking collars. Positions of camels can then be converted to spreadsheet format either as text (*.txt) or database (*.dbf) and imported into ArcView Tracking Analyst. An Internet-based GIS system that allows camel owners to access the database anywhere and at any time, using the latest mobile technology (mobile phone accompanied by GPS receiver and Wireless Application Protocol [WAP]), is on its way.

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Notes

1 In order to increase *awareness* about application of GIS for camels, the first author summarized the outcome of this study in UAE the local media (*Gulf Newspaper*, 5 February 2003) and international GIS media (*ArcUser Magazine* 6(3), July–September 2003).

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