Dust Storm Phenomena and Their Environmental Impacts in Kuwait

by

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Summary

Dust storms are one of the significant phenomena in the desert areas of the world. It is internationally agreed that days with visibility below 1000 metres due to dust present in the air are a result of strong winds. As Kuwait is part of the Arabian desert, which is identified as one of the major dust source, so dust storm occurrence is more frequent especially during summer. Dust storms in Kuwait are mainly associated with north and north westerly winds, which are locally known "Shamal". That is because this wind crosses the Iraqi and Arabian deserts before reaching Kuwait carrying a huge amount of dust and sand. There are are local dust sources within Kuwait which supply these winds with dust. Dust occurs in Kuwait in four main types:

1) Sand / dust storm.
2) Rising dust.
3) Suspended dust.
4) Haze.

There are many factors which play an important role in the occurrence of dust in Kuwait, they include the following:

1) Kuwait's location within the the great desert belt.
2) Lack of rainfall.
3) Lack of vegetation cover.
4) Surface air turbulence due to huge amounts of radiation.
5) Human activities such as over-grazing, off-road driving.

Dust and sand storms have a bad effect on environment in Kuwait. The main aspects of the environmental impact of dust which have been focussed on in this thesis, are:

1) Dust effects on vehicle body parts and the role of dust storms in road accidents due to poor visibility.

2) Dust effect on house parts and buildings.

3) Dust effects on human health from inhaling the fine dust particles which contain many organic and non-organic material. These materials, which are carried by dust, cause various type of allergies especially with respiratory system.

There are many methods which have been used to reduce the amount of dust which raised up in the air by strong winds. But it seems the most suitable method is tree planting which has many positive effectsother than stabilising sand.

CHAPTER ONE: INTRODUCTION

1.1) The Dust Problem: Dust and sand storms are very common phenomena in arid and semi-arid parts of world. Kuwait and its surrounding areas, as part of this zone, suffer from dust and sand storms more especially during summer, which is the driest season. The maximum frequencies of dust storms are in June and July. Dust storms are called locally "toze" and "simoom" meaning poison wind. The two factors which play the most significant role in dust and sand storm occurrence are strong winds and absence of vegetation cover. Human activities may also play an important role. Definition of dust phenomena are not simple. However it has been agreed internationally that visibility of less than 1000 metres due to dust is reported as a dust storm day. Such storms, mostly associated with north westerly winds have a harmful impact on Kuwait's environment. As a result of reduction in visibility, safety in transportation, such as take-off and landing of airplanes, ship movement in and out of the harbours and movement of road vehicles is impaired during the dust storm. In some accidents resulting in injury or loss of life and material may occur. Thus dust storms have a major effect on the country's economy. At the same time, material carried by dust and sand storms acts as an erosive agency, especially via large particles acting on the buildings and front faces of vehicle. The smallest particles affect the respiratory system by inhalation or by entry to the eyes or nose. Also, cultivated lands, roads, constructions in deserts, oil pipelines, etc. may be buried by the sand and dust moved during these storms. These constructions act as attractions for dust and sand in storms, encouraging deposition around them.

The basis of this thesis, therefore, is to answer the following questions:

1) How do strong winds and unvegetated surfaces affect the existence of dust ?

2) How badly do sand and dust storms affect transportation?

3) How are constructions eroded by dust and sand storms?

4) How badly is the people's health affected by dust and sand storms?

5) How effective are biological methods for sand control?

1.2) Objectives: The main objective of this study is to investigate the impact of the dust hazard on transportation, buildings and constructions, and people's health in Kuwait. In order to achieve this objective it is necessary to identify dust types and their occurrence, dust sources at local and regional scales, and the main factors which generate dust in Kuwait. To do this, it is necessary to consider existing studies of this problem in other places in order to get a wide view of the problem.

1.3) Study scope: This study is divided into three main sections, as follows:

1. The first focuses on the dust phenomena in Kuwait from a physical point of view, including the main generating factors, dust type classification, dust particle size, dust source, etc.

2. The second points out the environmental hazards and impacts of dust in Kuwait under three aspects of activity. These are, transportation,

buildings, and people's health.

3. The final part suggests and recommends methods of reduction of dust environmental hazards in Kuwait.

1.4) Study Area :

1.4.1) Location: There is no fixed date for the establishment of the town of Kuwait. The records of the English East India Company suggest that the town was built about 1716 A.D. (Abu-Hakima, 1983). The Danish traveller Niebuhr was first to put the name Kuwait on a map dated 1765 (Hakima, 1983). The State of Kuwait occupies the northeastern part of Arabian Peninsula. It is bounded in the east by the Arabian Gulf, to the north and west by the Republic of Iraq and in the west and south by the Kingdom of Saudi Arabia. Kuwait lies between 28° 30′ and 30° 05′ north of the equator and 46° 33′ and 48° 30′ east of Greenwich. The total area of Kuwait is about 17,818 sq. km. In addition, there are a number of offshore islands including, Bubiyan, Warba, Kubbar, Failaka, Mischan, Um Al-Nemmil, Auha, Qaruh and Umm At Maradim. The only island inhabited is Failaka and the largest one is Bubiyan.

1.4.2) Physical Features: In general the surface character of Kuwait is flat and gradually sloping towards the north east at an average gradient of one in five hundred. (Fuchs, Gathinger and Holzer, 1968). So, the average elevation ranges from the sea level in the east to about 300 metres in the south western part of Kuwait (Fuchs, Gattinger and Holzer, 1968; Halwagy, 1982; Al-Mutawa, 1985). The main surface physical feature of Kuwait can be characterized as follows :

a. Hills and Ridges: There are five hills areas which are distributed over Kuwait. The Jal Az-Zor hill extends from north west to south east direction for about 60 kilometres in length. The maximum height is about 145 metres (Halwagy, 1982; Fuchs, Gattinger and Holzer, 1968). There are two other hill ranges which are parallel to Jal Az-Zor but lower than it. They are Al-Laiah and Kura-Al-Maru hills. Ahmadi ridge runs parallel to the coast of Kuwait City. It reaches 137 metres in height (Al-Mutawa, 1985, Fuchs, Gattinger and Holzer, 1968; Halwagy, 1982). The Wara hill is a conical hill reaching about 30 metres in height (Halwagy, 1982).

b. Wadis: There are many small wadis in the country, but the main and largest one is Wadi Al-Batin, along the Kuwait-Iraqi border. Also, Wadi Al-Musannat which crosses the southern border near Manageesh (Fushs, Gattinger and Holzer, 1968) and Wadi Al-Shigaia which is located in the south west near the frontier with of Saudi Arabia are significant features (Ministry of Planning, 1985).

c. Salt Marshes: These occur on the coast, especially along the south western and north shores of the Bay of Kuwait (Halwagy, 1982).

1.4.3: Climate of Kuwait: The main characteristics of Kuwait climate are a hot, dry and dusty summer and cooler winter with a little rain. Chapter three discusses the climate of Kuwait in detail with special reference to dust activity.

1.4.4) Population: The population of Kuwait has increased dramatically in recent years because of immigration to Kuwait following the discovery of oil. Many foreigners came to Kuwait because the country is in need of manpower **(Table 1-1).**

CENSUS YEARS	KUWAITI	NON-KUWAITI	TOTAL
1957	113,622	92,851	206,473
1961	161,909	159,712	321,621
1965	220,059	247,280	467,339
1970	347,396	391,206	738,662
1975	472,088	522,749	994,837
1980	565,613	792,339	1,357,952
1985	681,288	1,016,013	1,697,301

Table 1-1: Kuwait population (Kuwaiti and non-Kuwaiti) growth from 1957 to 1985 censuses. (after: Ministry of Planning, pp.25, 1987).

The number of non-Kuwaiti in particular have increased. For example in 1957 the Kuwait census showed that 55% of population was native Kuwaiti and non-Kuwait was 45%, in 1970 Kuwaiti population was 47% and non-Kuwaiti reached 53%, and in the last census, in 1985, the Kuwaiti population was only 40.1% and non-Kuwaiti about 59.9%. The majority of non-Kuwaiti are Arabs, with Asians next in importance (Ministry of Planning, 1987).

1.4.5) Economy: The economy of Kuwait largely depends on oil and natural gas production (Al-Mutawa, 1985; Ministry of Planning, 1987 **(Table 1-2).**

Years	Oil (in 1000 barrels)	Natural Gas (in million cubic mertres)
1981	411,174	6,325.8
1982	300,221	4,605.2
1983	384,107	4,832.9
1984	424,617	5,191.5
1985	387,363	5,063.9

Table 1-2: Production of Oil and natural gas in Kuwait. (after: Ministry of Planning, pp.195, 1987).

Recently, the Kuwait government has tried to reduce economic dependence on oil. Therefore, it is encouraging the establishment of oil-related industries such as petrochemicals, and other non-oil-related industries (Al-Matawa, 1985). Agriculture has a small part in the country's economy because of poor soils, lack of irrigation water and climatic conditions.

1.5) Literature Review: The parts of the world which suffer from the dust and sand storms, are located in arid and semi-arid regions. Studies of these include; (Middleton, (A)., 1986; Péwé, 1981; Goudie, 1983; 1978). Australia (Laurie, 1943), United States (Idso, 1976; Warn, 1952; Wigner and Peterson, 1985; Vakata, Wilshire and Barnes, 1981), China (Shao-Jin, Mihg-Yu, Shao-Hon, Xi-Ming and Yeng, 1981), Egypt (Oliver, 1945; Banoub, 1970), Iran, Pakistan, Afghanistan, India (Middleton, 1986), Saudi Arabia (Sirag, 1984; Wolfson and Matson, 1986), Iraq (Al-Shalash, 1966; Al-Najim, 1975; Coles, 1938), Bahrain (Houseman, 1961), Kuwait

(Safar, 1985; Al-Kulabe, 1984; Goudie, 1983; Middleton, (A)., 1986; Gharib, 1984). In most of these countries dust storms have been given local names (Middleton, (A); (B); 1986; Goudie, 1978; 1983). These local names describe the phenomena, for example, Simoom in Kuwait means the poison winds (Middleton, 1986). The name relates to the wind character which is hot, dry and dusty. The Egyptian Kamsin ,dusty wind, which mean fifty days (Birtwistle,1946; Middleton, (A),1986), in Sudan Haboob which simply means in Arabic wind (Freeman,1952),and in Iran, there is Foehn type wind which called Garmsil meaning hot wind or hot storm. This type of wind often raises large quantities of dust (Middleton, (B),1986).

Recently dust and sand storms have been observed by satellite. These satellite images have made available a new and unique source of information allowing a better and wider understanding of these phenomena. For instance, satellite images have provided information on topics such as distribution, dimensions, structure, dynamics, sources and evolution of dust clouds (Grigoryev and Kondratyev, 1980). Using METEOR-18 satellite images of Russia, particularly Kazakhstan and Central Asia, three source areas of dust have been identified (Grigoryev and Kondratyev, 1980):

1) North-eastern coast of the Caspian Sea.

2) South-eastern coast of the Caspian Sea.

3) North-eastern coast of the Aral Sea.

In the United States, images from the GOES-L (Geostationary Orbit Environmental Satellite) revealed one of the largest dust storms recorded over the High Plains in February 1977 (McCauley, Breed, Grolier and Mackinnon, 1981). Also, two main dust sources have been identified from the satellite images. One of these sources was Clovis-Portales area, Portales valley, in the southern High Plains near the eastern New Mexico-Texas border. The other source was near the Colorado-Kansas border (McCauley, Breed, Grolier and Mackinnon, 1981). In the Middle East, there are two examples of satellite dust storm observations. The first observation was in the Mesopotamia lowland and northern part of Arabian Gulf by Gemini-12. The dust storm appears on ITOS-I T.V. image as four sub-parallel strips in July, 1970 (Vinogradov, Grigoryev and Lipatov, 1972). This dust storm was due to a strong north wind. The wind velocity at a height of 1-1.5 km was 40 m/sec. This type of dust storm is known locally as "Great Shemal" (Vinogradov, Grigoryev and Lipatov, 1972). The second observation was in Saudi Arabia and was unique. Unexpectedly, the NOAA-7 thermal infrared satellite during the night of 22nd July 1982, detected a large comma-shaped sand storm in the north-eastern part of Saudi Arabia (Wolfson and Matson, 1986). At Qaisumah (Saudi Arabia) at 0000 GMT on 23 July 1982, the maximum height of this dust storm was 1.8 km (Wolfson and Matson, 1986).

At a world scale there are many regions and zones which act as dust sources. But, the main and major regions of dust sources can be identified as follows : Central and Western Africa, the southern coast of Mediterranean, north eastern Sudan, the Arabian Peninsula and the Lower Volga and northern Caucasus (Idso, 1976; Goudie, 1979; Nickling, 1986; Goudie, 1983; Nalivkin, 1986; Péwé, 1981; Péwé, Péwé, Péwé, Journaux and Slatt, 1981). Dust in Kuwait comes from two main sources, local and regional. Local sources are located within the Kuwait boundary whilst regional ones are located in surrounding countries such as Iraq, Iran and Saudi Arabia. Both of these two source areas and their implications for dust storms in Kuwait are discussed in chapter four.

One of the main characters used to define dust storms is the visibility range. Dust storms have been identified internationally as having a visibility range less than or equal to one kilometre (Safar, 1985; Al-Kulaib, 1984; Coles, 1938; At-Najim, 1975; Goudie and Wells, 1986; Banoub, 1970; Péwé, 1981). But some scientists consider that dust storms may occur with an internal visibility of more than 1 km. For instance, Orgil and Schmel (1976) regard dust storm visibility as equal to or less than 11.3 km, Nickling and Brazel (1984) equal to or less than 1.6 km and Freeman (1952) equal to or less than 2 km. In contrast, Oliver (1945) regards dust storm as being defined by a visibility range equal or less than 700 metres and Péwé, Péwé, Péwé , Journaux and Slatt (1981) 800 metres. Some scientists have proposed the term for a dust storm with visibility equal to or less than 1 km of "dust fog" (Loewe, 1943).

Dust storms have been classified according to visibility range. For example, Oliver (1945) recognized ordinary dust storms with visibility range equal to or less than 700 metres, severe dust storms when visibility range is between 50-200 metres and very severe storms when visibility is less than 50 metres. In order for a dust storm to rise and develop in the air there are many factors which play an important role in this process. These factors are discussed fully in chapter four. But, the two main factors are strong winds and dry, loose surfaced and sandy types of soil (Middleton, 1984; 1985; 1986; 1987; Durst, 1936; Prospero and Carlson, 1972; Ing, 1972; Lourensz and Abe, 1983; Warn, 1952; Coles, 1938; Idso, 1976).

In many parts of the arid and semi-arid regions, dust and sand storms occur more frequently during dry seasons and in those places which are suffering from drought. For example, it has been found that the drought in the Sahel area increased the dust storm frequency (Middleton, 1985; 1987; MacLeod, 1976). Similarly there has been periodic occurrence in frequency of dust storms in the United States, in the southern part of Great Plain (Wigner and Peterson, 1985; Warn, 1952; Orgill and Sehmel, 1976; Finnel, 1954; Pollard, 1978). The dust bowl and its dust storms of 1930's in the United States was an unforgettable experience for people (Worster, 1979). In Phoenix, Arizona, dust storms are frequent during the summer time due to strong winds which are associated with outflow of cold air from thunderstorms (Brazel and Hsu, 1981; Wigner and Peterson, 1985). Dust storm frequency in Phoenix is about 12 days annually (Idso, 1976). In the USSR, in the Prikhankaisky valley in the eastern part of Russia, in April 14, 1956, a strong dark dust storm occurred. It covered an area of about 20,000 sq km and wrought havoc for 5 - 8 hours (Nalivkin, 1986). Sand and dust storms over Russia originate in two main source areas, the virgin land of the Kazakhstan and Kazahhstan Desert, and Central Asia (Nalivkin, 1986). The dust frequency in Kazahkstan is about 60 days annually (Goudie, 1978). Australia is one of the countries in the southern hemisphere affected by dust storms.

They are more frequent in the western part of Australia where a large dust source is available (Middleton, 1985; Loewe, 1943). Alice Springs in the centre of the continent has the highest annual average of dust storms. Over a twenty six year period the maximum annual total of dust storms was 65 days **(Table 1-3)** (Middleton, 1984).

Station	Location		Annual Average
Alice Springs	23° 49'S	133° 54'E	10.8
Onslow	21° 40'S	115° 07'E	8.1
Mildura	34° 14'S	142° 05'E	6.3
Tibooburra	29° 26'S	142° 01'E	4.7
Daly Waters	16° 16'S	133° 23'E	4.5
Oodnadatta	27° 34'S	135° 27'E	3.5
Charleville	26° 25'S	146° 16'E	1.9
Kalgoorlie	30° 47'S	121° 28'E	1.8

Table 1-3: Annual average days of dust storm distribution occurrence in selected stations in Australia (1957-1982). (after: Middleton, pp 47, 1984).

Dust storms in Australia commonly occur in spring (September-October) and summer (February-March) (Middleton, 1985, Loewe, 1943). For instance, on 8th February 1983 at 3 pm, severe dust storms advanced over Melbourne city. The storm blow over the open grazing and wheat lands of northern Victoria and south west New South Wales. This area became a desert after experiencing drought (Lourensz and Abe, 1983). The dust storm reached a height of 2800 metres according to the report of an aircraft pilot, but the dust storm height reduced on approaching Melbourne to 320 metres (Lourensz and Abe, 1983). The visibility was reduced to less than 100 metres in the city, the airport was closed and traffic came to a virtual standstill (Lourensz and Abe, 1983). As a result of this dust storm the Victorian State Soil Conservation Authority estimated that 106 kg per hectare (1 ha.=10,000 m^2) of dust was deposited (Lourensz and Abe, 1983).

The Sahara Desert is the largest dust source in the world (Idso, 1976; Goudie, 1983; Middleton, Goudie and Wells, 1986). The Sahara supplies most of the dust storms which occur in west, central and north Africa with dust and sand, via wind such as Khamsin, Harmattan, Haboob (Goudie, 1978, 1983; Dubief, 1979). The Sahara Desert can be divided into five regions (Middleton, Goudie and Wells, 1986):

1. Bodele Depression alluvial plains in Niger and Chad.
2. Southern Mauritania, northern Mali and central southern Algeria.
3. Southern Morocco and western Algeria.
4. Southern fringes of Mediterranean Sea in Libya and Egypt.
5. Northern Sudan.

Saharan dust has been transported long distances. In some cases it has reached South America, crossing the Atlantic Ocean (Idso, 1976). The Atlantic has been known for a long period as the "Dark Sea" due to a remarkable reduction in horizontal visibility. According to the geological record, deposition of earlier dust from the Sahara is demonstrated by deposits of loess (Moroles, 1979). Those dust particles which settle in the Atlantic, may have an ecological importance. By providing additional nutrients to sea they may promote the growth of phytoplankton and contribute to the Atlantic fishing stock (Lundholm, 1986). Saharan dust reached Gibraltar on 5th December 1950, reducing visibility to less than 1000 yards (914.4 metres) in a dust storm, accompanied by strong south-south westerly winds. Later, a perceptible deposit of reddish brown dust was noticed in many areas of Gibraltar (Ward, 1951).

The general character of the Middle East climate is rainy winters and hot and dry summers. This type of climate favors the occurrence of dust storms. Therefore, they are more frequent in Egypt (Banoub, 1970; Birtwistle, 1946; Durward, 1937; Freeman, 1952; Oliver, 1945); Iran (Middleton, B., 1986), Iraq (Al-Najim, 1975; Al-Shalash, 1966; Coles, 1938), Bahrain (Houseman, 1961), Saudi Arabia (Siraj, 1984; 1985; Middleton, (A), 1986), and Kuwait (Safar, 1985; Al-Kulaib, 1984, Khalaf, 1980). In Egypt the dust storm is more frequent during winter and spring **(Table 1-4)** (Middleton, 1985; Birtwistle, 1946; Banoub, 1970). Visibility during the Khamsin is reduced to less than 50 metres (Banoub, 1970). Large dust and sand storm particles may cause extensive damage to aircraft engines and propellers by the penetration of dust particles (Banoub, 1970). Furthermore, difficulty arises for the pilots in taking off and landing due to poor visibility (Banoob, 1970). Iran is one of the countries widely affected by dust storms. Dust occur in most parts of the country (Middleton, (B), 1986). Zabol in Iranian Seistan, between Iran, Pakistan and Afghanistan borders, has the highest dust storm occurrence in Iran **(Table 1-5)**(Middleton, (B), 1986).

Airports	Element	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Period
Mersa Matrouh	Dust Storm	1.3	1.4	1.3	1.0	0.8	0.2	0.1	0.0	0.1	0.4	0.9	2.0	47
	Rising Dust	3.0	3.3	2.3	2.3	1.6	0.9	1.1	0.3	0.6	1.3	1.1	2.3	65
Alexandria	Dust Storm	0.3	0.5	0.6	0.3	0.3	0.0	0.0	0.0	0.1	0.1	0.0	0.2	42
	Rising Dust	1.2	1.3	1.6	1.5	0.7	0.3	0.2	0.0	0.0	0.3	0.3	1.0	65
Port Said	Dust Storm	0.2	0.2	0.4	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.5	42
	Rising Dust	0.8	0.8	1.3	1.3	0.6	0.1	0.1	0.0	0.0	0.3	0.4	0.7	65
Cairo Airport	Dust Storm	0.4	0.5	0.6	0.8	0.4	0.1	0.0	0.0	0.1	0.1	0.1	0.5	47
	Rising Dust	2.6	2.9	3.2	3.0	2.2	1.2	0.1	0.1	0.2	0.7	0.8	2.7	65
Menya	Dust Storm	0.2	0.0	0.1	0.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42
	Rising Dust	0.4	0.6	0.8	1.5	1.6	0.6	0.0	0.1	0.0	0.3	0.1	0.2	65
Luxor	Dust Storm	0.0	0.1	0.2	0.6	0.6	0.1	0.1	0.1	0.0	0.0	0.0	0.0	47
	Rising Dust	0.5	0.5	1.1	1.3	2.1	0.4	0.2	0.3	0.1	0.2	0.2	0.3	65
Aswan	Dust Storm	0.4	0.1	0.3	1.0	1.1	0.1	0.0	0.6	0.1	0.1	0.6	0.1	60
	Rising Dust	1.4	3.1	5.9	6.1	4.9	2.6	3.1	4.1	1.0	1.0	1.7	2.1	66

Table 1-4: Dust storm and rising dust average number of days occurrence in International **Airports** in Eygpt. (After; Banouf, pp25, 1970).

Location	Average Frequency
Zabol (south east)	80.7
Abadan (south west)	43.1
Dezful (south west)	40.0
Hamadan (west)	34.4
Jask (south	27.3
Yazd (central)	24.0
Bander Abba (south)	23.1
Sabzevar (north east)	21.1

Table 1-5: Average annual frequency of dust storm days in Iran (After; Middleton, (B), 1986).

The active season for dust storms in north west Iran is from April to July, central Iran from February to July and along the Arabian Gulf between Abadan and Jask from May to July (Middleton, (B), 1986). In Yazd, Central Iran, dust storm wind velocity may reach 17 m/s and the visibility is reduced to 20 metres (Middleton, (B), 1986). Those types of storms can strip vegetation of leaves and cause severe damage to buildings by corrosion (Middleton, (A), 1986). The airfield on Bahrain Island is affected by low visibility during the summer time. This low visibility is due to dust haze which is associated with a north-westerly wind, known locally as "Shamal" (Houseman, 1961). Bahrain is relatively far from the Arabian Peninsula which is 44 km distant (Houseman, 1961). Low visibility, below 1000 metres, mainly occurs between May to July. The worst visibility period affecting the airfield is in June and the worst period of day is in the afternoon (Houseman, 1961). Dust storms frequently occur in Iraq (Al-Shalash, 1966; Coles, 1938; Al-Najim, 1975; Goudie, 1978, Middleton, (A), 1986). Most dust storm cases are associated with the north westerly wind "Shamal" as in Bahrain. For instance, in Baghdad 53 per cent of dust storm cases are associated with north westerly winds and only 28 per cent with south easterly winds. In the 81 per cent of dust storm cases (Al-Najim, 1975) the Shamal wind is generally stronger at Shaibah than elsewhere in Iraq. So, September and October are the best months for aviation in Iraq owing to low dust, rain and thunder storm frequencies (Coles, 1938). Dust storms occur in many parts of Iraq **(Table 1-6)**.

Location	Average Frequency (days)
Shaibah (south)	37.6
Diwaniyah (south)	35.9
Hinaidi (central)	33.2
Baghdad (central)	21.5
Basra (south)	14.7

Table 1-6: Average of number of dust storm days over Iraq. (After: Goudie, pp293, 1978)

The maximum dust storm frequencies occur in May and October in northern Iraq, from March to July in the central part, and from June to July in the southern part of Iraq (Coles, 1938; Al-Shalash, 1966; Al-Najim, 1975). Also, Iraq is recognized as one of the major dust sources in the region (Houseman, 1961, Safar, 1985; Goudie, 1983). Dust reduction of visibility range in Iraq causes major hazards for aircraft landing and taking off. Also, dust storms are causes of Asthma, Bronchitis and other lung diseases as a result of the irritations produced within the body by sharp edged particles (Al-Najim, 1975). They also carry numbers of bacteria and viruses (Al-Najim, 1975).

The Arabian Peninsula is recognized by Idso (1976) as one of the major dust sources in the world. Saudi Arabia occupies about four-fifths of the Arabian Peninsula (Abd El Rahman, 1986), the dust and sand storms are most frequent throughout Saudi Arabia **(Table 1-7 & Figure 1-1)** (Siraj, 1984; Goudie, 1978; Middleton, (A), 1986; Anton and Vincent, 1986).

Locations	Average Frequency
Riyadh (central)	12.7
Dharan (east)	11.3
Tabouk (north west)	10.8

Table 1-7: Average of dust storm days occurrence in Saudi Arabia. (After: Goudie, pp 293, 1978)

Dust storms are more frequent and stronger over the eastern coast (Arabian Gulf coast) than the western coast (Red Sea coast), and in northern parts than the southern part of Saudi Arabia (Siraj, 1984). Dust storms in the eastern region are mostly dominated by Shamal winds (north westerly wind) (Siraj, 1984; Anton and Vincent, 1986). In this

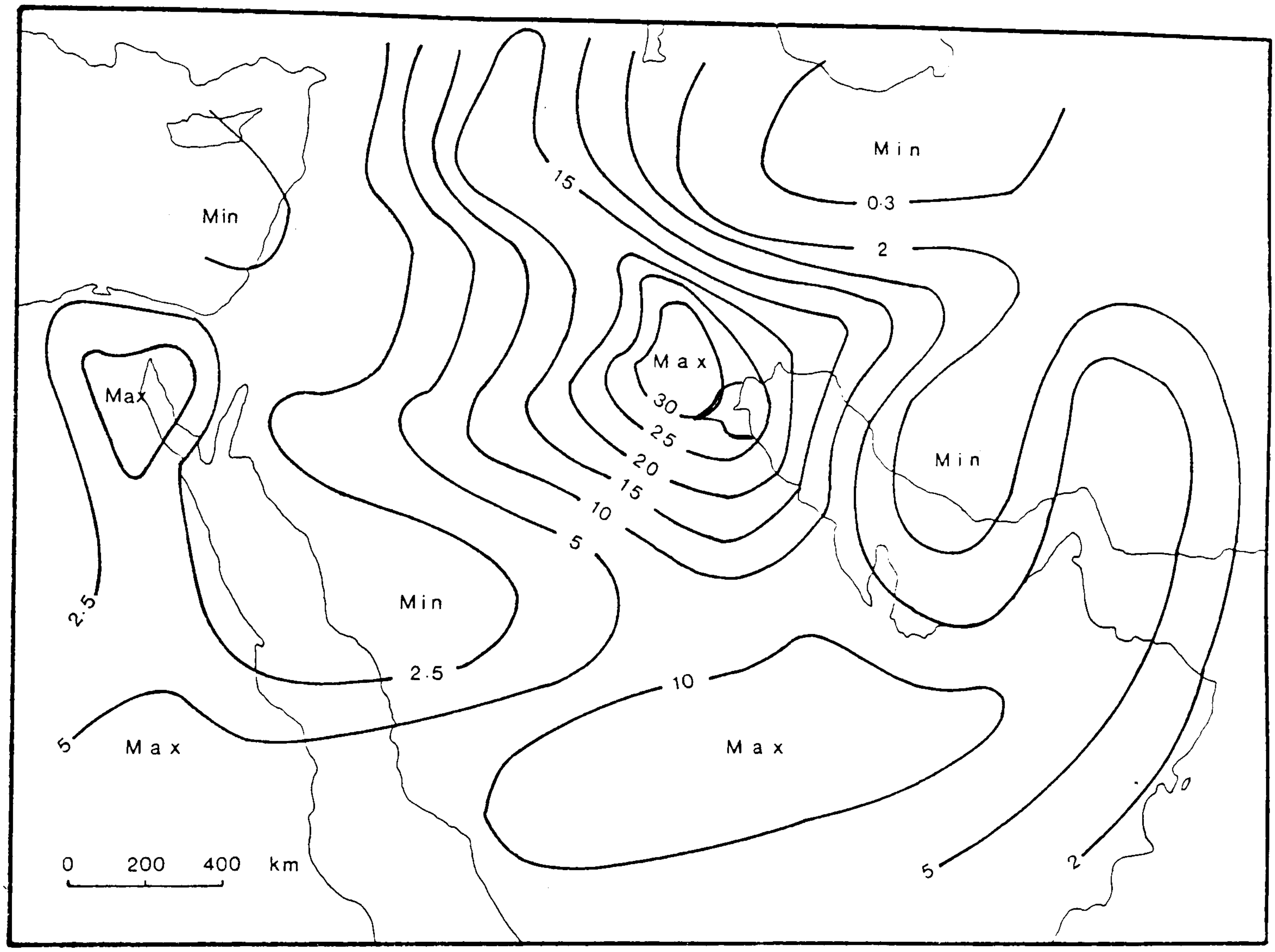


Figure 1-1: Arithmetic mean of annual occurrence "Dust Storms" with visibility less than one kilometre, from 1947 to 1968. (Number of days) (After; Khalaf, et al. ,vol. 1, figure 1.18, 1980).

region, dust sources are Rub Al Khali Desert (south and south east), Na Nefud (north and north east), Ad Dahna (east) and Jafurah (east) (Anton and Vincent, 1986; Holm, 1960; Siraj, 1984; Cooke, Brunsden, Doornkamp and Jones, 1985). Jafurah and Ad Dahna are parallel deserts in the eastern region of Saudi Arabia. The sand colour of Jafurah desert is pale brown while Ad Dahna is strongly reddish (Anton and Vincent, 1986). In Dhahran City, in eastern Saudi Arabia, on 17th April 1964 at 1700 GMT, there was good visibility and light easterly surface wind prevailing. But, suddenly the wind shifted to a northerly direction and increased in speed to between 40-46 knots (20.6-23.6 m/s). It was accompanied by blown thick dust and the visibility dropped to zero. The visibility ranged between zero and 300 yards (274.3 metres) until noon of the 18th. Then in the evening of the 18th visibility improved to more than 3 miles (4.8 km) (Siraj, 1964). Dust storms are more frequent in Dhahran than sand storms **(Table 1-8)**.

Month	Dust storm	Sand storm
January	6	6
February	9	9
March	11	6
April	16	5
May	23	10
June	18	5
July	19	2
August	8	1
September	8	0
October	2	0
November	1	0
December	5	0

Table 1-8: Monthly average of dust storm and sand storm days in Dhahran City over 5 years. (After: Siraj, pp.1,2, 1964)

These low visibility ranges due to dust storms cause a major aviation hazard in Dhahran International Airport (Siraj, 1984). Along the eastern coasts of the Red Sea the dust storms are frequent. They are named locally 'Aziab' in Saudi Arabia and 'Al-Ghoba' in the Yemen Arab Republic (Siraj, 1980; 1984). Aziab is defined by Siraj (1980, 1984) as a hot and dry wind from southerly quadrant. It is usually a strong wind which raises a lot of dust and is more frequent during March and April. The Aziab carries the dust from Tihama plains, along the eastern coast of the Red Sea (Siraj, 1980; 1984). These types of dust storms cause much damage to human health, especially of those people who suffer from respiratory infections. For instance, a report from the Ophthalmology Department of the Central Hospital in Jeddah, during an Aziab period from 19-20 April 1979 showed that the number of patients complaining of ear, nose and throat diseases increased due to the Aziab occurrence (Siraj, 1980; 1984). Dr. Abdiel Rehman Hasnain, Director of the Central Hospital in Jeddah, stated that "it has been clear to us that during the dusty days, the asthma and semi-asthma attacks have increased more during this month than other months of the year". (Siraj ,p.7, 1980).

Therefore, in the Gulf region the regional dust sources are alluvial plains of southern Mesopotamia, Syrian Desert, Jordan and North Saudi Arabia (Middleton, Goudie and Welles, 1986). Dust and sand storms with material from these sources commonly occur in Kuwait and neighbouring countries such as Iraq, Saudia Arabia, Iran and the other Gulf countries. Kuwait is part of the major dust source area of the Arabian Peninsula (Middleton, (A), 1986; Idso, 1976; Goudie, 1983; Safar, (A), 1985; 1982) and dust storms occur here more frequently during summer time especially in June and July **(Table 1-9)** (Safar, 1982, (A);(B), 1985; Al-Kulaib, 1984; Al-Nakshabandi and El-Robee, 1988)

Month	Sand/Dust Storm	Rising Dust	Suspended Dust	Haze
January	1.1	3.7	3.1	7.7
February	1.2	4.3	4.4	7.5
March	2.1	6.1	4.7	7.6
April	3.2	6.1	5.2	7.4
May	4.2	6.7	6.2	7.5
June	4.8	10.3	4.7	6.4
July	4.4	8.4	5.7	7.4
August	2.3	8.3	5.2	8.9
September	0.6	5.1	6.0	11.3
October	1.5	3.6	5.7	10.7
November	0.4	2.9	4.0	10.3
December	1.1	3.4	3.2	8.8

Table 1.9 : Average number of days of dust type occurrence at Kuwait International Airport (1982-1984) (After: Safar, pp. 46, (A), 1985)

Sand and dust storms, and rising dust mainly originate from local source areas. In contrast, the suspended dust originates in the neighbouring countries (Safar, (A), 1985; Al-Kulaib, 1984; Al-Nakshabandi and El-Robee, 1988). Dust storms are mainly associated with north westerly winds **(Table 1.10)** (Safar, (A); (B), 1985; 1982; Al-Kulaib, 1984; Al-Hajj, Farmer, Al-Hassan and Saif, 1981).

North West	North East	South East	South West
80%	4%	10%	6%

Table 1-10: Percentage of hours of dust and sand storms occurrence related to the wind direction (1962-1982) (After: Safar, pp.31, (B), 1985)

Dust storms are initiated by wind velocities of 4.5 m/s or more (Al-Kulaib, 1981; Al-Nakshabandi and El-Robee, 1988).

Dust fall in Kuwait is one of the major concerns of the Environmental Protection Council(formerly the Occupational Health and Industrial Pollution Control Section). This council carried out one of the first comprehensive studies of dust fall published as "Dust Fallout in Kuwait" in 1978. The dust fall project started in 1969 with seven locations and in 1973 a further ten locations were added. These locations are Shamiya, Sulaibikhat, Khaldiya, Funtas, Shuaiba, Ahmadi, mid-town of Kuwait city, Mutlaa, Farwaniya, Salmiya Airport, Maqwa, Messila, Abu-Halifa, Jaleeb Al-Shuyukj, Sulaibiya and Shaab **(Figure 1.2)** (Occupational Health and Industry Pollution Control Section, 1978). This project is continuing under the Environmental Protection Council, under the Ministry of Public Health, which publishes results as an annual report. Many studies are carried out on dust sources in Kuwait by the Environmental and Earth Sciences Division of Kuwait Institute for Scientific Research. Most of these studies concentrate on local sources of dust storms, within Kuwait

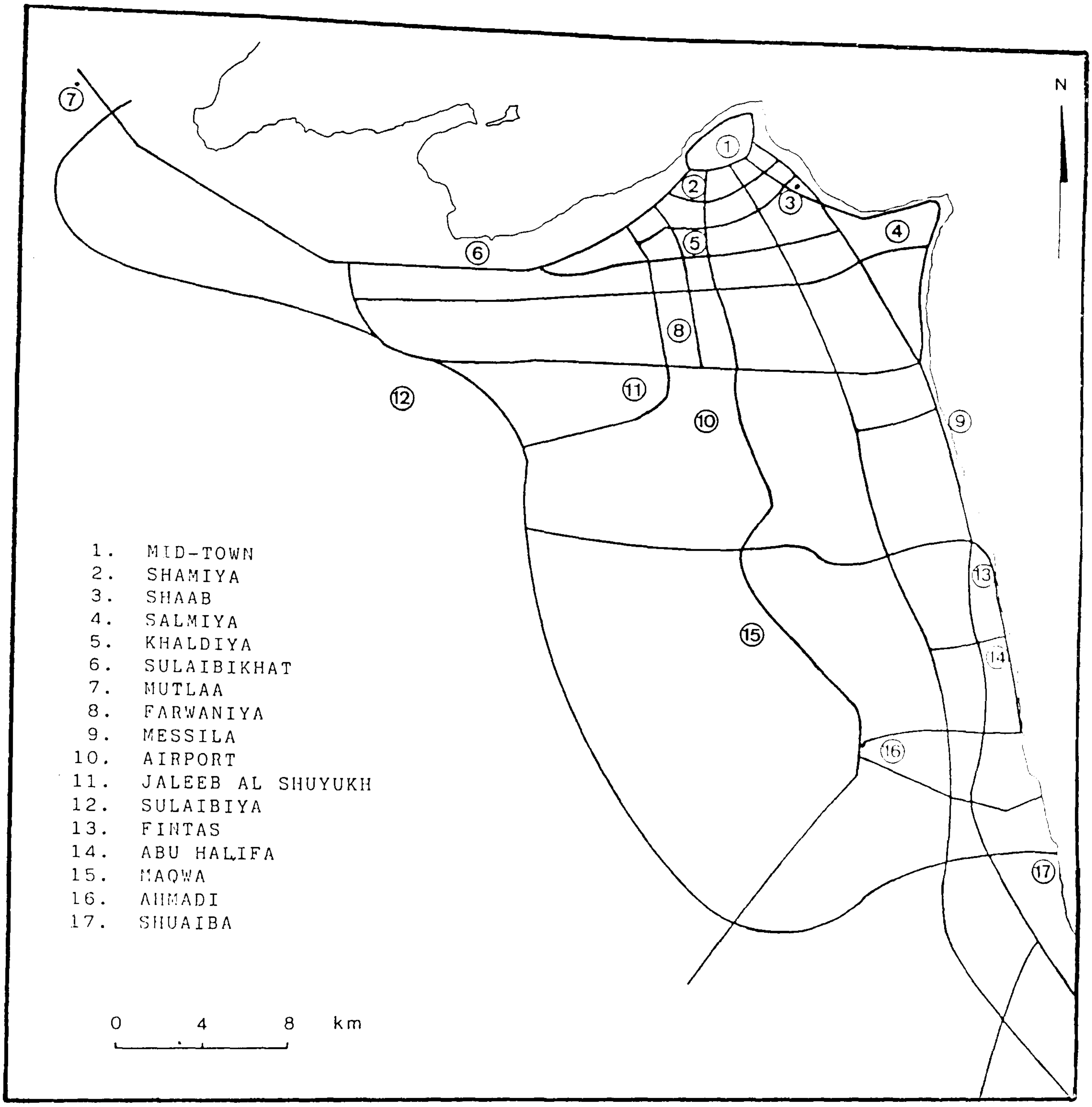


Figure 1-2: Location of sampling sites for governmental dust fall-out survey in Kuwait.

(After; Occupational Health & Ind. Pollution Control Section, pp.17, 1978).

State boundary. The main comprehensive study, produced in two volumes, was "Dust Fallout (TOZE) in Kuwait: Mineralogy; Granulometry and Distribution Pattern" in 1980. The main object of this study was to identify the local potential sources of dust storm sediments in Kuwait, and to study their granulometrical and mineralogical characteristics (Khalof, Kadif, Gharif, Al-Hashash, Al-Saleh, Al-Kadi, Deszouki, Al-Omran, Al-Ansari, Al-Huti and Al-Mudhian (A), (B) 1980). Further literature which describes and discusses local dust storm sources in Kuwait has been published (Gharif, 1983; Foda and Al-Attiah, 1982; Gharif, Al-Hashash, Asem, Attasi and Foda, 1982; Halwagy and Halwagy, (A), 1974; Khalaf and Al-Hashash, 1983; Khalaf, Al-Kadi, Gharif, Foda and Al-Hashash, 1982; Khalaf and Gharib, 1985; Khalaf, Gharib and Al-Kafi, 1982; Al-Nakshafandi and El-Robee, 1988). On the other hand, the regional dust sources have not been discussed and investigated. Regional sources are important as well as local ones particularly in the case of suspended dust. In many cases it has been observed that dust has travelled long distances; indeed some has been identified as Saharan dust.

There are many factors which have been identified as playing important roles in generating dust storms. These factors include soil and sand characteristic, vegetation cover factors and climatic factors (McTainsh, Burgess and Pitblado, 1989; Al-Nakshfandi and El-Robee, 1988). Climatological factors generally have a more important influence than the two other factors (McTainsh, Burgess and Pitblado, 1989; Al-Nakshafandi and El-Robee, 1988; Middleton, 1985). In Australia, the frequency of dust storms increases with decreasing annual average rainfall (McTainsh; Burgess and Pitblado, 1989). Increase in rainfall amount leads to increase in the soil moisture which binds sand particles together, and dust storm frequency decreases (Al-Nakshabandi and El-Robee, 1988). During winter and spring in Kuwait the desert is partially covered by plants, and dust storm frequency is correlated with rainfall ($\geq$ 0.1mm) in Kuwait, the result was r=-0.82 (Al-Nakshabandi and El-Robee, 1988).

Dust and sand storms have a significant impact on the environment. As a dust cloud rises, the horizontal visibility range reduces. This low visibility affects transportation media such as vehicles, planes and ships. For instance, in the United States many dust-related vehicle accidents have occurred on Interstate 10 in Arizona due to the poor visibility (Hyers and Marcus, 1981). As a result of the increase in dust-related accidents, the Department of Transportation in the State of Arizona established on Highways 8 and 10 a highway Dust Storm Alert System (Burritt and Hyers, 1981). In Kuwait, on April 15, 1977, a sudden severe dust storm occurred carrying a huge amount of dust. This caused many road accident casualties (Al-Kulaib, 1981). The fine dust particles, bacteria, pollen and fungi which are carried by dust storms all have an important effect on human health (Péwé, 1981; Al-Awadi, 1973; 1983). The materials which are typically carried by dust storms were reported to cause allergies among many of residents of Arizona State (Leathers, 1981; Péwé, 1981). Valley fever in Arizona is caused by Coccidioides immitis, a fungus carried by dust storms (Leathers, 1981). Such materials suspended in the air can be inhaled and may cause disorders of the respiratory system (Environment Protection Council, (A); (B), 1984).

Dust-related allergies in Kuwait have been studied by Dr. Al-Awadi (1973) and in Ahmadi city by Dr.W.M. Wilkinson, (1964).

Dust and sand particles act as corrosive agents on buildings, and damage crops. It has been noticed that wooden fence posts may be sculpted into bizarre shapes or worn through by wind-driven sand (Wilshire, Nakata and Hallet, 1981). A California Highway Patrol car was found on Highway 58, east of Calvente Creek, with its windshield frosted. Many travellers report loss of their car windows as they travel against the direction of the wind (Wilshire, Nakata and Hallet, 1981). Two empty 10,000 gallons water tanks were ripped from their pads and rolled over in the foothills of the Tehachapi Mountains. Many immature crops are damaged by sandblasting (Wilshire, Nakata and Hallet, 1981). In Sulabiyah, Kuwait, the blowing sand buried buildings, destroyed fences and blocked highways. It affects corn growth by bruising corn seedlings. Dust and sand storms have harmful effects on vegetation by drying leaves and burying growing plants (Al-Nakshabandi and El Robee, 1988). One of the most important sources which discusses the whole range of dust storm phenomenon and its impacts on man's health and property is "Desert Dust: Origin, Characteristics and Effect on Man" edited by Troy L. Péwé, (1981).

In order to reduce the environmental hazard of dust storms, it is necessary to control dust raising factors. One of the main dust raising factors which can be controlled is amount of vegetation cover. Whenever, the vegetation cover increases the dust storm frequency decreases (Al-Nakshabandi and El-Robee, 1988; McTainsh, Burgess and Pitblado, 1989). There are mechanical methods of control of dust raising such as concrete obstacles, oil mulching or using tree branches. These methods can be used as a temporary controls (Shakatrah and Osman, 1984; Al-Sary, 1984)' and are important in protection of growing shelter belts for the first two years (Abdul Wahid, 1982). The most successful method however is the planting of tree and shelter belts. It has been used successfully in many countries including China, Iran, Iraq, Saudi Arabia, Kuwait (Yongyao, 1987; Chen, 1987; Xingliang, 1979; Zhasnda and shu, 1981; Ondenge, 1984; Tavakoli, 1982; Gati, 1984; Abass, Awad and Hassain, Undated; Al-Mutawa, 1985; Al-shaaby, 1984). These are discussed fully in chapter eight.

CHAPTER TWO: METHODOLOGY

2.1) Introduction:

Most of the literature which has been reviewed in Chapter One mainly points to the physical characteristics of dust storms. In particular literature concentrated on dust storm frequency, sources and deposits. On the other hand, some dealt with environmental dust-related hazards such as Péwé (1981) in Desert Dust. In the case of Kuwait, the main organizations which study the dust storms are the Meteorological Department, Environment Protection Council and Kuwait Institute for Scientific Research. The Meteorological Department studies are concentrated on the meteorological view of dust storms, such as Safar (1985). The Environment Protection Council of the Ministry of Public Health studies focussed on amount of dust deposits and their components. The main study which was carried out by Kuwait Institute for Scientific Research was Dust Fallout (Toze) in Kuwait in two volumes. This study pointed out the local dust storm sources. This investigation of the environmental impact of the dust hazard on transport, buildings and health in Kuwait is based on the following data sources.

2.2) Data Collection: The data collected for the dust-related hazard investigation can be divided into three types of sources; published materials, personal communications, and fieldwork questionnaires.

2.2.1) Published Materials: They are divided into two main parts:

(a) Government publications published by governmental departments such as the Environment Protection Council, the Kuwait Institute for Scientific Research, the Department of Traffic, the Central Statistical Office, Kuwait Center for Allergic Diseases, and the Meteorological Department. Some of these data are crude statistical data whilst others are in an analytical form such "Dust Fallout in Kuwait", 1978.

(b) Books and articles written about dust phenomena throughout the world. The majority of studies about dust have been focussed on three areas : the United States, the Great Sahara Desert and Australia. They analysed out dust generating factors, dust frequency, sources and deposits.

2.2.2) Personal Communications: Personal communications have been made in order to clarify certain dust-related hazard effects. For instance, Dr. K. Al-Kazmy, Kuwait Center for Allergic Diseases, has been contacted to discover the role of dust in allergy diseases in Kuwait. Also, some officials in the Municipality of Kuwait, have been questioned in order to ascertain the cost of removing dust from the roads and motorways.

2.2.3) Field Work: The questionnaire is, as Nyamweru, Ferguson and Ngau (1986), defined it, an instrument of measurement and data collection which is used to compile information from people. Therefore the questionnaires used in this study have been designed to investigate and measure the environmental impact of dust on people's lives and properties. This provides data which are not available from published materials about effects of dust in Kuwait. The questionnaire has been divided into four parts: personal and general information, dust storms and houses, dust storm and vehicles, and dust storms and people's health.

a) Personal and General Information: This part covers essential personal data relating to respondents such as gender, nationality, and age. Also, it covers general information about the dust storm occurrence in the respondent country of origin, in case of non-Kuwaiti. Respondents were further asked to compare dust frequency between present and twenty years ago in Kuwait.

b) Dust Storms and Houses:. The purpose of this part is to investigate and measure how dust storms affect the fabric of the house. Homes have been characterized by their location, and type. Dust impacts affect several parts of the house, including windows, gardens, living room, bed room, electrical equipment. Assessment of these impacts has been measured by a point score method.

c) Dust Storms and Vehicles: The aim of this part is to estimate the impact of dust and sand storms on vehicles parts, including windows, lights, engine, etc. Effects have been measured by a point score method. Road accidents have been investigated to establish whether poor horizontal visibility, due to dust storms, has been a significant cause.

d) Dust Storms and People's Health: This part, as the others, measures and investigates dust effects on human body parts, such as eyes, nose, face, throat, and lungs. Diseases and allergies which may be caused by inhaling fine dust particles are investigated.

This questionnaire survey was carried out in Kuwait between December 1986 and February 1987. In Kuwait, there are four governorates, Capital, Hawalli, Ahmadi and Jahra. A total of 400 questionnaires were distributed. The questionnaires have been distributed over these four governorates, 100 questionnaires for each. The population differs from one governorate to another, and thus the questionnaires were distributed in each governorate according to their percentage of the total population in the 1985 census **(Table 2.1 & Figure 2.1)**.

Governorate	Population	% of Population	No. of Questionnaire
Capital	167,768	9.9	40
Hawalli	944,439	55.6	222
Almai	305,062	18.0	72
Jahra	280,032	16.5	66
Total	1,697,301	100.0	400

Table 2.1: Distribution of population numbers, percentage and questionnaire numbers by governorates in Kuwait, according to 1985 census.

A pilot survey was carried out in March 1986 using samples from Ahmadi Governorate and some students of the Geography Department in Kuwait University. Many questionnaires were returned incomplete, and others were not returned. Generally, the respondents to this pilot survey did not answer the questions in a reliable way. The pilot study was 300 questionnaires, but the response was 155, which is half of the sample.

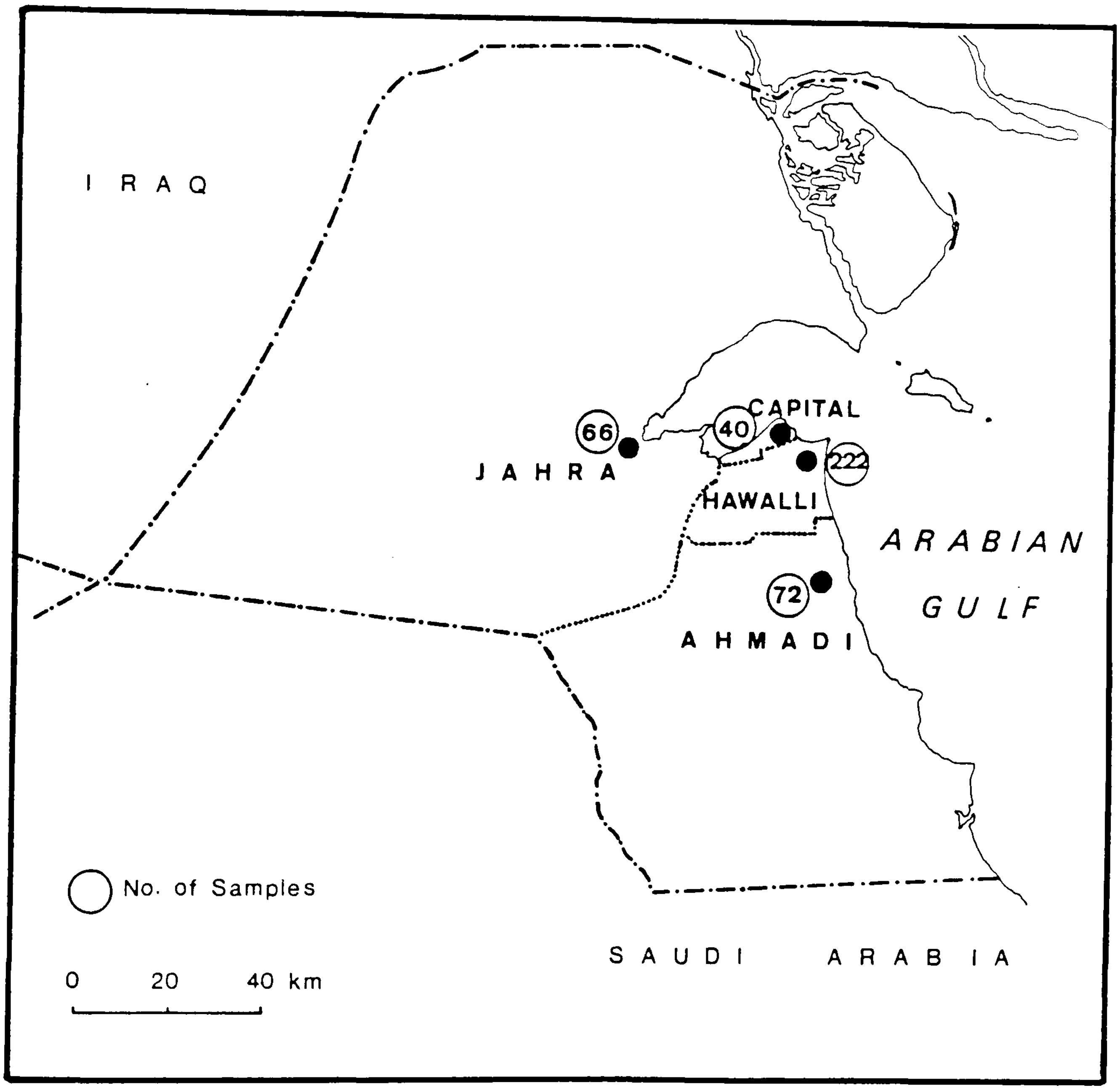


Figure 2-1: Questionnaire sample from each governorate.

Therefore, to obtain a good response and to produce a socio-economically homogeneous sample, for comparison dust effects, teachers were chosen as a sample for this survey for the following reasons:

(1) A considerable proportion of the population is illiterate especially among women. According to 1985 census, there were 26.4% among the Kuwaiti population over 10 years of age who are illiterate and 20.4% of non-Kuwait. This percentage is higher among Kuwaiti females (36.9%). In contrast, the percentage of educated people is relatively low. For instance, 4.1% of Kuwaitis are graduates or post-graduates and 9.3% of non-Kuwaitis **(Table 2.2)**.

Education Status	Gender	Kuwaiti	Non-Kuwaiti
1) Illiterate	Male	15.5	21.2
	Female	36.9	19.1
	Total	26.9	20.4
2) Secondary and below Uni. level	Male	14.0	16.6
	Female	11.2	18.6
	Total	12.7	17.4
3) Graduate & Post-graduate	Male	4.9	10.2
	Female	3.3	7.7
	Total	4.1	9.3

Table 2.2: Percentage of Kuwaiti and non-Kuwaiti, males and females population, over 10 years of age in Kuwait according to 1985 census.
Note: Female percentage based on the total female population in the same manner for males. The total percentage is based on the total population of both Kuwaitis and non-Kuwaitis.

(2) In some circumstances, it is hard to interview or talk with the women, due to prevailing social customs. In the case of female teachers, it is easier to clarify questions, especially, if they have their own schools. Women's opinion is important because of their role in taking care of the house and family.

(3) Ordinary people may have some difficulties in answering or understanding some questions, for example questions which identify allergy names. In such cases, the teachers are likely to give better responses.

(4) Contact and communication with teachers are easier than with the ordinary people. They have an ability to understand questions on their own. This saves a lot of time so that is no need interview each person individually.

(5) Teachers also have direct contact with weather each day, because they have to move through the school yard for their classes. Classes are not in closed buildings, classes rooms do not have air conditioning facilities. Therefore they are directly affected by weather conditions.

(6) Most of the teachers, males and females, have their own cars. Therefore they are able to evaluate the effect of dust on their cars.

(7) Most of the teachers have the similar living standards. This standardises certain characteristics, allowing more accurate evaluation of the effect of dust.

Despite these precautions, there were 31 questionnaires which were not returned or returned incomplete. But generally, the response was good, 369 respondents (92.3%) returning complete questionnaires **(Table 2.3)**.

Governorate	No. Questionnaires	No. Respondents	% Respondents
Capital	40	40	100
Hawalli	222	194	87.4
Ahmadi	72	70	97.2
Jahra	66	65	98.5
Total	400	369	92.3

Table 2.3: Number of questionnaires and respondents by governorates and percentage of respondents

Samples were selected from various locations within each governorate. These locations were selected by lot in following way. The name of localities were been written on pieces of paper and then appropriate number sample locations chosen at random. The locations were located as follows: 5 in Capital, 9 in Hawalli, 6 in Ahmadi and 3 in Jahra **(Table 2.4 & Figure 2.2)**.

Capital Gov.	Hawalli Gov.	Ahmadi Gov.	Jahra Gov.
Shamiya (8)	Hawalli (25)	Funtas (12)	Al-Taima (22)
Keefan (8)	Rawda (24)	Riqqa (12)	Al-Qasr (22)
Faiha (8)	Salmiya (25)	Hadiya (12)	Al-Jahra (22)
Nuzha (8)	Jabriha (24)	Subahiya (12)	
Daiya (8)	Rumaithia (25)	Ahmadi (12)	
	Salwa (24)		
	Mushrif (24)		
	Abrak Kheetan (25)		
	Subah Al-Salim (25)		

Table 2-4: Distribution of questionnaires by localities in each governorate.

Following this permission was sought from the Education Authority in each governorate to distribute the questionnaires in their schools. The questionnaires were handed to the headmaster of each school, for distribution among the teachers. The questionnaires were distributed only among the teachers living in that locality or in that governorate. General characteristics of the questionnaire respondents are shown in the following table **(Table 2.5)**

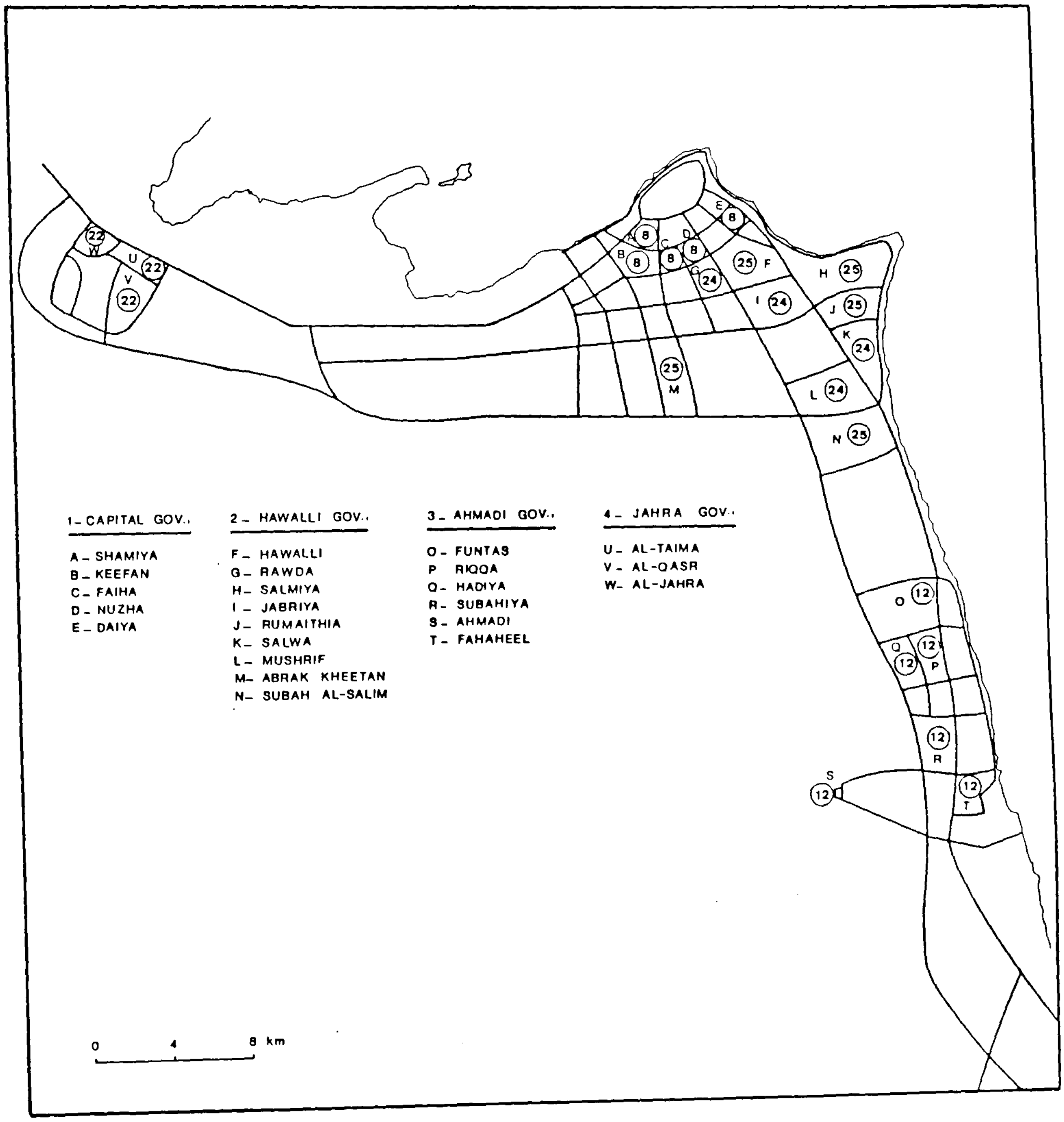


Figure 2-2: Questionnaire sample from localities within each governorate.

Itemize	Capital	Hawalli	Ahmadi	Jahra
No. Respondents	40	194	70	65
Sex:				
1) Male	26	109	40	34
2) Female	14	85	30	31
Nationality:				
1) Kuwaiti	38	100	43	22
2) Non-Kuwaiti	2	94	27	43
Car owning:				
1) Car Owner	37	166	64	44
2) Not car owner	3	28	6	21
House Type:				
2) Villa	23	81	19	13
2) Traditional House	11	20	25	14
3) Flat	5	91	26	38
4) Not stated	1	2	0	0
Age group:				
1) Less than 20 years	0	1	0	0
2) 20-30 years	16	42	30	23
3) 30-40 years	16	101	27	30
4) 40-50 years	8	35	13	10
5) More than 50 years	0	8	0	1
6) Not stated	0	7	0	1

Table 2.5: General characteristics of the respondents of the questionnaires by the governorates of Kuwait.

2.2.4) Data Analysis: In the first stage of analysis of the collected data simple statistical methods were used, including mean, median, quartile, standard deviation and coefficient of variation. Further statistical methods were used to study the relationship between variables. Suitable statistical packages for this analysis are available for use the ICL 3980 main frame computer of Glasgow University. The two packages which have been used for analyzing the data in this study are Minitab and SPSSX. The Minitab package was used to analyse climate data related to the dust phenomena. Minitab was also used to analyse other data related to the environmental impacts of dust. The SPSS X package was used to analyse the questionnaire by cross tabulation methods.

PART ONE

CHAPTER THREE : THE CLIMATE OF KUWAIT

Kuwait occupying a relatively small part of the north eastern corner of the Arabian peninsula, occupies 17818 square kilometers. By virtue of this location Kuwait is part of Arabian Desert which covers most of the Arabian peninsula.

Therefore, Kuwait's climate is "dry , hot, desert type" as described in the World Survey of Climatology. The two main features of Kuwait's climate are;

1) There are large temperature ranges between summer and winter, and day and night. The monthly mean maximum January temperature is 18°C, and in July is 44.7°C. The monthly mean minimum January temperature is 7.7°C, and in July is 29.1°C.**(Table 3.1& Figure 3.1)**.

Months	Daily Max. Temp.°C	Daily Min. Temp.°C	Monthly Mean Temp.°C
JAN	18.0	7.7	12.8
FEB	20.7	9.4	15.0
MAR	25.8	13.4	19.5
APR	31.3	18.5	24.8
MAY	38.2	23.9	31.1
JUN	43.4	27.5	35.8
JUL	44.7	29.2	37.2
AUG	44.5	28.4	36.5
SEP	41.6	27.7	33.1
OCT	35.4	19.7	27.2
NOV	26.4	13.8	19.9
DEC	19.9	8.7	14.2

Table 3.1: The daily maximum and minimum temperature and monthly mean at Kuwait (1962-86).

The mean daily temperature range in January is 10.3°C , and in July is 15.5°C. On the other hand, the monthly mean in January is 12.8°C, and in July is 37.2°C. That means the seasonal temperature range is 24.4°C. This high range of temperature is one of the main characters of the desert and Kuwait climate. This range is modified near the coast because of the effect of the sea. The temperature is highest about 1500 hours local time **(Table 3.2)**.

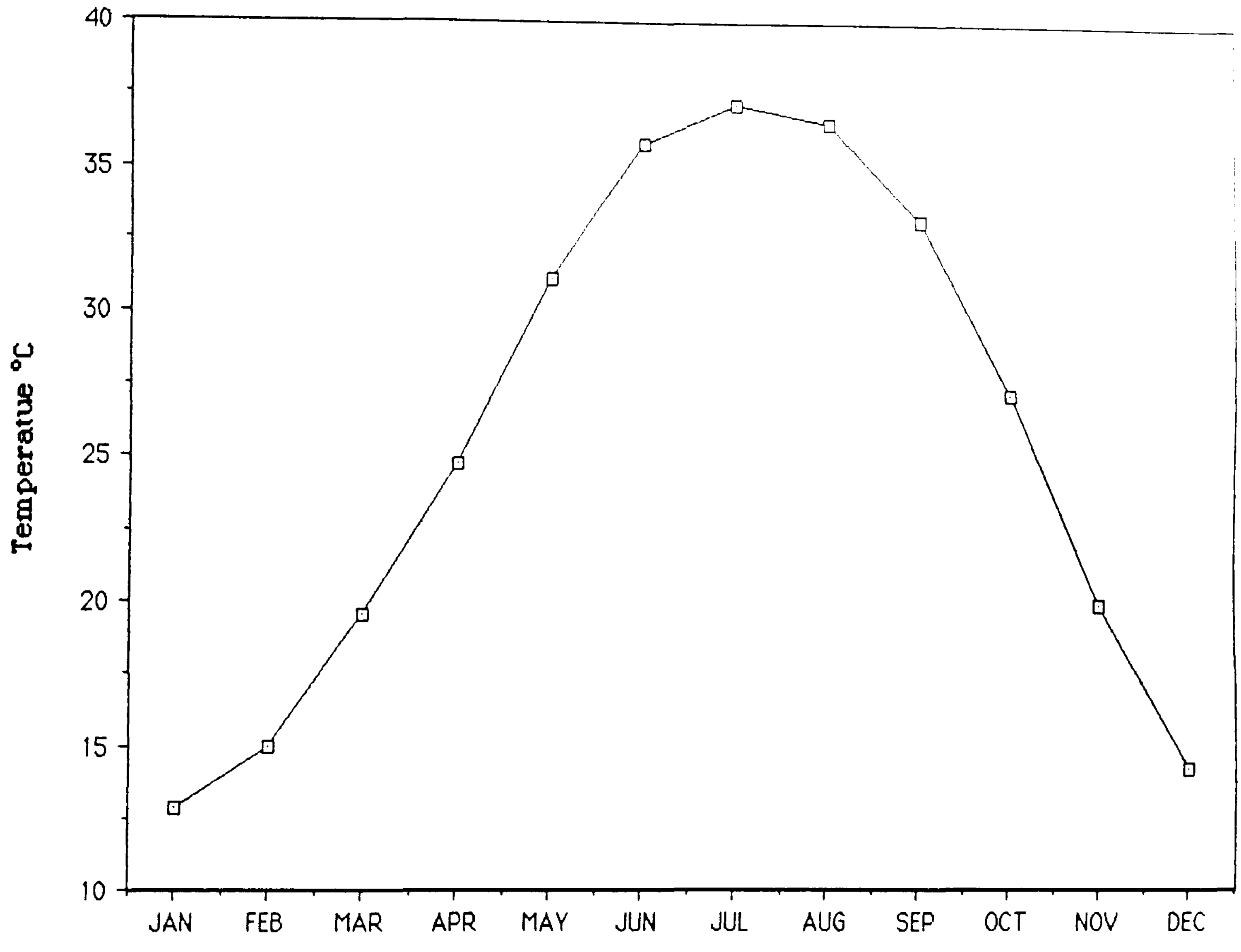


Figure 3-1: Monthly mean temperature in Kuwait (1962-1986).

	G.M.T. Hours (LMT 3.17 hours fast on GMT)							
MONTH	0000	0300	0600	0900	1200	1500	1800	2100
JAN	9.6	8.7	11.3	16.3	17.6	14.9	12.7	10.9
FEB	11.8	10.8	14.1	18.9	20.0	17.5	15.1	13.3
MAR	15.8	14.6	19.6	24.2	25.1	22.4	19.5	17.4
APR	20.1	19.3	25.3	29.1	29.3	26.6	23.7	21.6
MAY	25.8	25.2	32.2	36.2	36.7	34.2	30.5	27.7
JUN	29.4	28.7	36.5	41.5	42.7	39.9	35.5	31.9
JUL	31.4	30.2	37.8	42.9	43.9	41.6	37.1	33.8
AUG	30.8	29.5	37.2	42.7	43.7	40.7	36.3	33.1
SEP	27.3	25.5	33.6	39.8	40.9	37.0	32.6	29.3
OCT	22.3	21.1	27.7	33.9	34.5	30.1	26.6	23.9
NOV	16.0	15.1	19.7	25.1	25.8	22.3	19.5	17.3
DEC	10.5	9.6	12.9	18.1	19.2	16.2	13.7	11.7

Table 3.2: The hourly mean temperature °C observations of Kuwait for period of 1962-1973 . (After: Al-Kulaib,1981).

2) There is only a small amount of rainfall. The mean annual amount of rainfall is 115.1 mm. It is concentrated in Autumn, Winter, and Spring.(**Table 3.3**) .

Month	Monthly Mean	Monthly Maximum
Jan	27.8	73.2
Feb	15.9	95.9
Mar	12.1	50.5
Apr	17.6	67.0
May	4.7	19.0
Jun	0.02	0.5
Jul	0.0	0.0
Aug	0.0	0.0
Sep	0.0	0.0
Oct	3.5	56.6
Nov	12.7	107.6
Dec	20.8	57.9

Table 3.3: The monthly mean and maximum of precipitation (mm) for period of 1957 to 1980. (Compiled from: Climatological Summaries).

The highest amounts of rainfall are in December,January, February, with a small secondary maximum in April. Generally, the rainfall from December to March is caused by the westerly depressions (al-Kulaib, 1984). In April the secondary maximum of rainfall is significant, this being caused by localised thunderstorms which are called locally "Sarrayat"(Meteorological Department, 1983). The other rainfall characteristic is that its annual value is very variable.

Figure 3.2 shows that 48% of years have less than 100 mm of total rainfall and that 8% have rainfall total of more than 212 mm **(Table 3.4).**

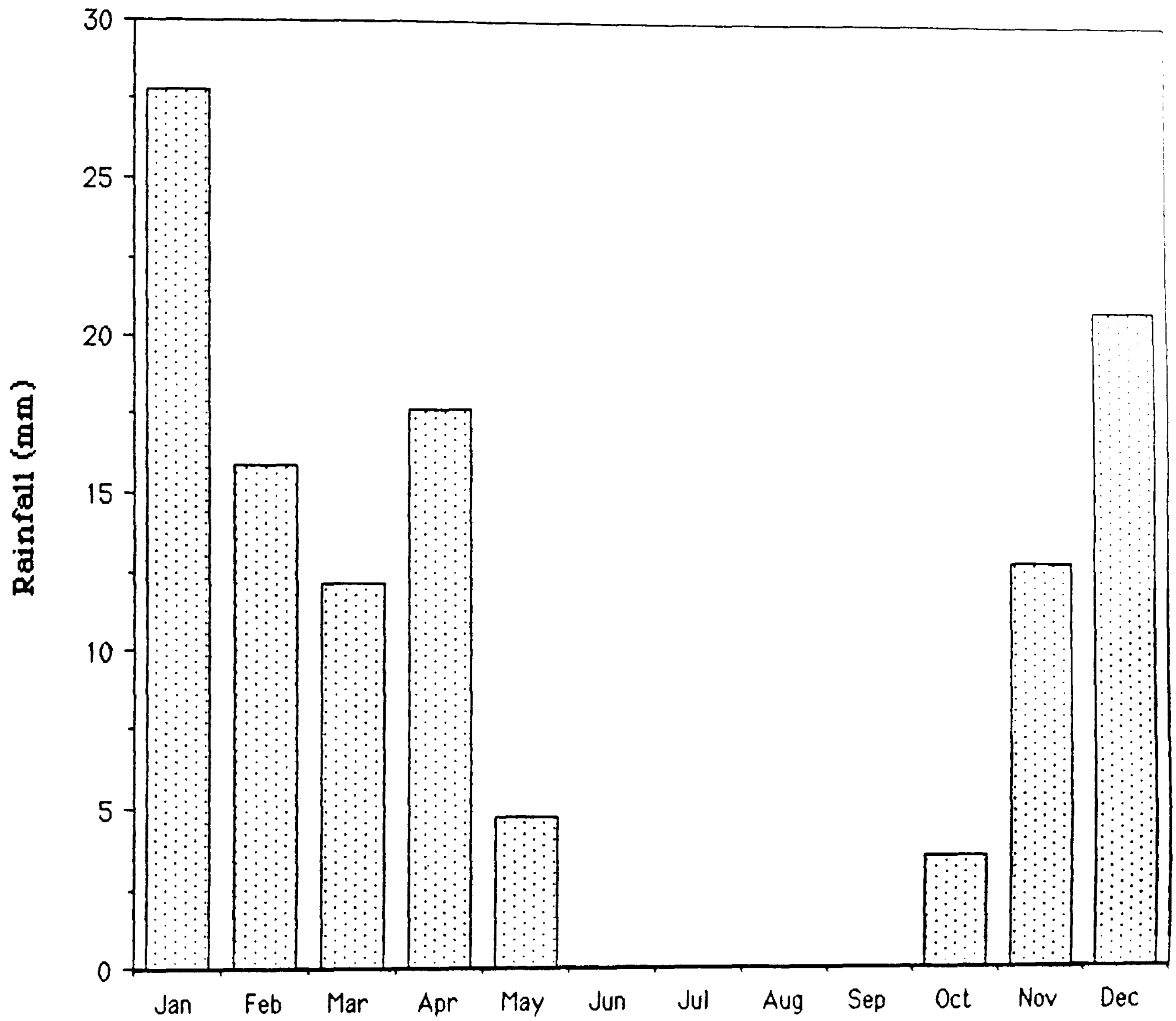


Figure 3-2: Monthly mean of precipitation (mm) for period of 1957-1980.

Total of Annual Rainfall m.m	≤50m.m	51≤100m.m	101≤150m.m	151≤200m.m	212≤250m.m
% of Years with Rainfall in Given Range	8 %	40 %	36 %	8 %	8 %

Table 3.4: Percentage of years with given range of rainfall in Kuwait over period 1962-1986.

The climate of Kuwait is influenced by several factors. The main factors are:

1) Solar Radiation:

Kuwait is located between 28°45′ and 30°05′ north of equator. Therefore, the sun reaches a maximum elevation of 84° on 21 June and reduces to 37° on 22 December (Al-Kuliab,1984). That means, that the amount of heat received during summer time is very much more than in winter, for two reasons:

1) The sun's elevation is greater and its incidence more direct in summer than winter.

2) Day length is longer in summer than in winter. During summer it reaches 14 hours and 2 minutes, reducing to 10 hours and 15 minutes in winter (Sharaf,1980).

In summer values of global radiation are extremely high. The mean monthly value in June is 738 $cal/cm^2/day$ (Climatology Dept.,1983) **(Table 3.5 & Figure 3.3)**

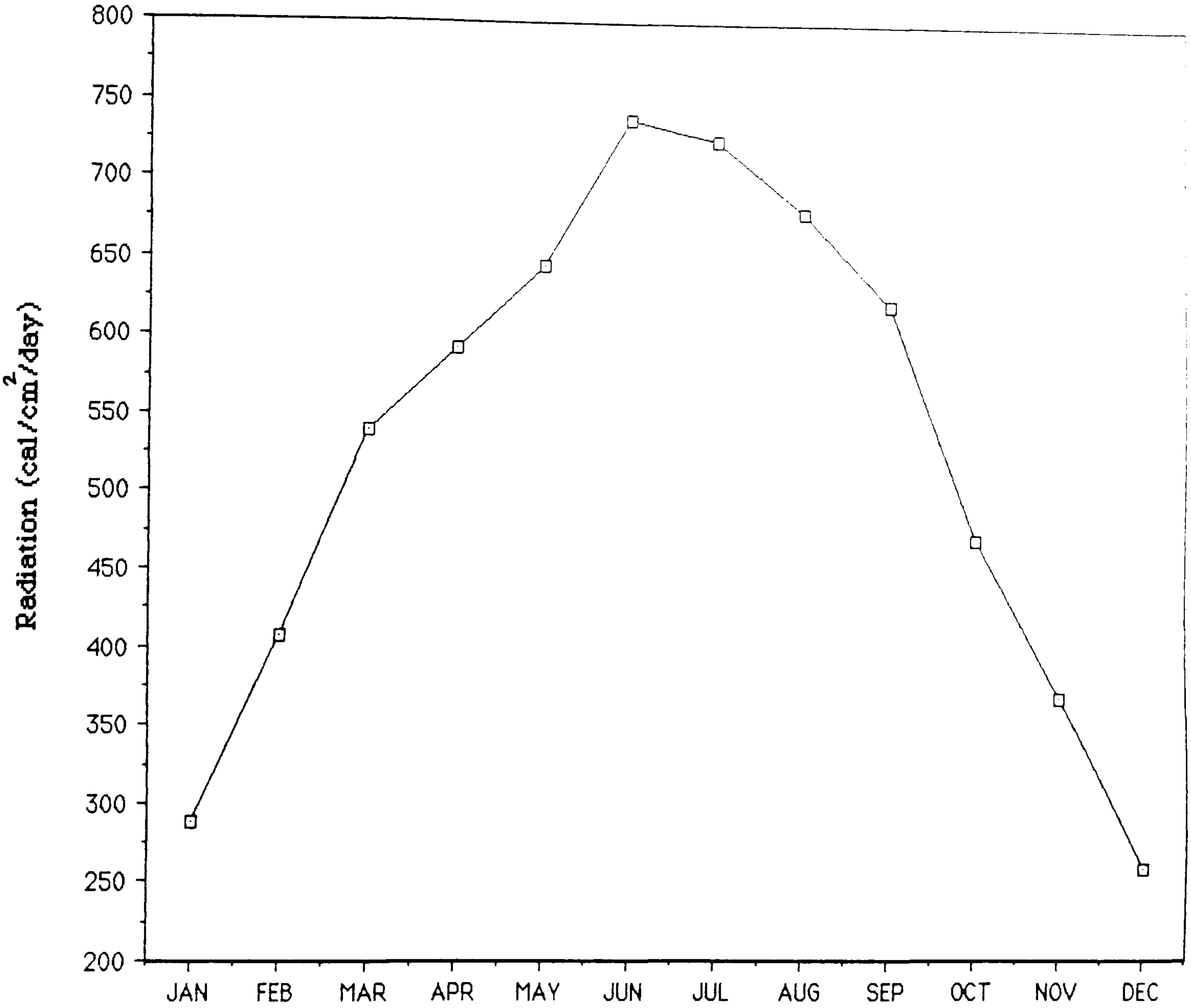


Figure 3-3: Monthly mean value of global radiation in Kuwait ($cal/cm^2/day$).

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN	288	408	540	592	645	738	725	679	620	470	368	259
DAILY HIGHEST	453	545	631	720	760	792	780	726	681	634	458	381
DAILY LOWEST	32	81	82	374	298	687	648	639	572	244	216	46

Table 3.5: Monthly values of global radiation in Kuwait (cal/cm^2/day) (April 1974- March 1975) (Source; Climatological Summaries,Climatology Dept.,1983).
(S.I. units: multiply by 41880 per J/m^2/day)

2)Air Masses:

Various type of air mass influence the climate of Kuwait. Some of these air masses reduce the temperature in summer and vice versa. Since Kuwait occupies a relatively small area, and there are no distinct topographic features, the impact of an air mass can be felt all over the country. Air masses which come from the south reach the country freely, since there are no topographic features to hinder movement. But, those coming from Asia to the north, which are typically cold and dry, cannot reach the country as freely because of mountains ranges to the north of Kuwait, especially the Zagros Range in Iran which act as a block.

The air masses which influence the climate of Kuwait and their relative frequency are shown in **(Figure 3.4)**:

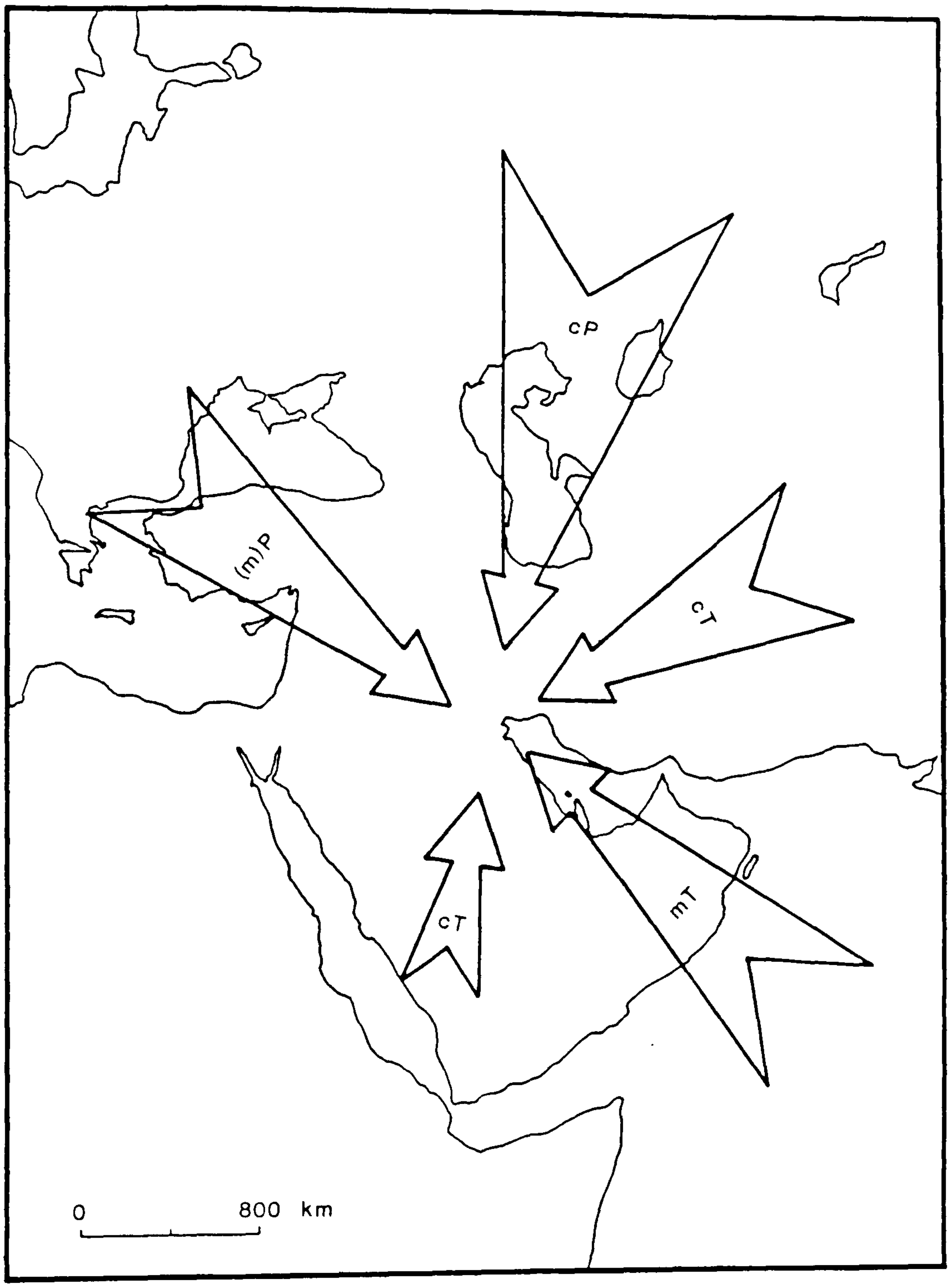


Figure 3-4: The main air masses which influence Kuwait.
(After: Al-Kulaib, p.15, 1984).

1) Continental Polar (cP):

The regional source of continental polar air mass lies in the northern part of Asia, Siberia, where the winter temperature range from -15°C during day time to -25°C or lower at night. Therefore, it is dry and cold air mass. It reaches Kuwait by occupying the cold sector of the Mediterranian depressions (Al-Kulaib, 1984). It causes north or north west winds, which are named locally "Shamal". In January in such condition the temperature ranges between 11°C to 15°C during day, and 5°C to 8°C at night (Al-Kulaib, 1984). Surface inversions are frequent. Sometimes thick suspended dust, rising dust, or dust storms may occur due to strong Shamal winds (Al-Kulaib, 1984). During March and April as cold air masses moving toward the south heat is constantly added. When surface winds are northerly in direction stable condition dominate, but whenever the winds shift to a southerly direction instability is increased because of some moisture has been added. Then local afternoon thunderstorms occur (Al-Kulaib, 1984).

2) Maritime Polar ((m)P):

This air mass forms in the north Atlantic Ocean. It reaches Kuwait dry and cold because during its long journey over the European and west Asian land masses it loses most of its moisture. In other words, it becomes modified maritime polar (Al-Kulaib, 1984). But, it is less cold and dry than the continental polar air mass (cP). It reaches Kuwait during winter time behind the Mediterranean depressions (Al-Kulaib, 1984). During the summer, this air mass may expand over Europe and part of the Mediterranean, even into the northern part of Arabian peninsula producing north easterly winds, clear skies and a maximum temperature lower than average (Al-Kulaib, 1984). When monsoonal low pressure over the north western part of Indian develops east of the modified Atlantic maritime polar air mass the pressure gradient becomes steep. As a result of this situation strong Shamal winds (N.W.) are produced and are accompanied by extensive dust storms which may blow 8 to 10 hours daily (Al-Kulaib,1984).

3) Continental Tropical (cT):

This air mass come from two different regions :

A) The first source is the central Arabian peninsula. Thus, it is hot and dry. It influences the Kuwaiti climate during spring and summer by causing the temperature to increase above the normal. In spring it appears in the warm sector of western depressions. In summer it follows the Arabian thermal lows. It causes some of the dust storms or suspended dust which are associated with south to south west winds (Al-Kulaib,1984).

B) The other source is the north western part of India. The effect of this air mass is felt during summer time over Iraq and the eastern part of the Arabian peninsula. It is associated with large low pressure systems which extend over north west India, Iran, and the Arabian peninsula. These low pressure systems, being located east of Kuwait produce northerly "Shamal"winds, producing over Kuwait hazy skies and dust storms. It is noteworthy that this "Shamal" wind has been heated adiabatically while descending from the Zagros mountains, causing a Föhn effect (Al-Kulaib, 1984). This wind thus causes the air temperatures in Kuwait to increase above normal summer values.

4) Maritime Tropical Air Mass (mT) :

The main character of this air mass is that is warm and moist. Its origin is the Arabian Sea, which is part of Indian ocean. It occurs in winter and summer. In winter it is relatively warm and results from the passage of Mediterranean depressions causing south to south east winds, which are called locally "Kaust" (Keeton, 1928). During the second half of summer, this air mass reaches Kuwait as the result of thermal low pressure.

3) Pressure Systems:

In general at latitudes of around 30° north and south the subtropical is influenced by the subtropical high pressure where the descending air of the Hadley cell reaches ground level (Goudie and Wilkison, 1977; Kellogg and Schneider, 1977; Bihariy, 1978; Lockwood, 1985). Therefore, the sky is generally cloudless and clear, and stability is characteristic. That does not mean that low pressure systems do not occur. There are some local thermal low pressures systems and depressions passing through the area as a result of differences in the heat balance between water and land. Kuwait's location between 28° 30′ and 30° 05′ north of equator means that it is part of Asian subtropical zone. Kuwait is north of the northern position of the intertropical convergence zone (ITCZ). The ITCZ over the northern hemisphere reaches about 25°N in July over the land north of the Indian Ocean and 5°-10°N over the Indian ocean. During January it moves to about 15° south over land, and close to the equator over the water (Henderson-Sellers and Robinson, 1986).

The main seasonal pressure distribution over Kuwait is:

1) During Winter:(Figure 3.5)

During winter season the intertropical convergence zone moves

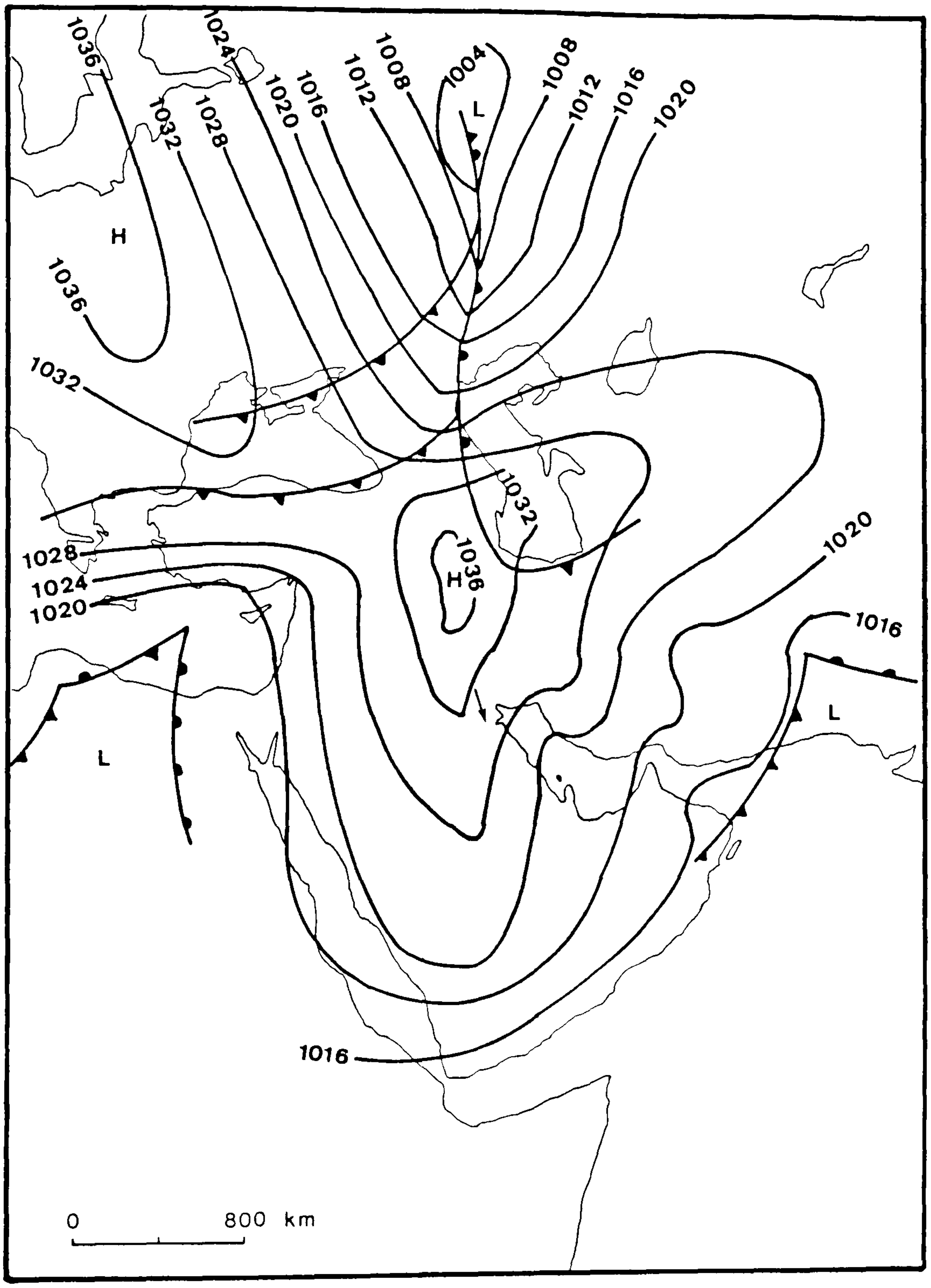


Figure 3-5: Pressure distribution during January(mb).

(After: Al-Kulaib, p.28, 1984)

towards southern hemisphere. Therefore, Kuwait is under effect of high pressure, especially that extending from the northern part of Asia, Siberia (Sharaf, 1980; Al-Kulaib, 1981; Lutgens and Tarbuck, 1986). The Siberian high pressure has three ridges extending from it : i) one of them lies over the Anatolian plateau, ii) the second one extends over the Iranian plateau, iii) and, the last one lies over the Arabian peninsula. There is another high pressure zone in north Africa, over the Sahara (Sharaf, 1980; Al-Kulaib, 1981). Conversely, there are low pressure cells over the water bodies around the country. These cells are over the Arabian Gulf, Red Sea, Arabian Sea, and Mediterranean Sea.

The average pressure reaches about 1035mb. in high pressure zones, and 1015mb. in low pressure zones (Sharaf, 1980; Al-Kulaib, 1984). In consequence of this pressure distribution the country is mainly under the influence of the cold and dry north westerly "Shamal" wind (Keeton, 1928).

Winter Depressions :

One of the main winter weather features of Kuwait is the frontal depression. It is important because (Al-Kulaib, 1984) ; i) it carries most of the total rain received by Kuwait , ii) it brings warm southern winds to Kuwait during winter time, and iii) it is responsible for dust storms in Kuwait during winter. The original source of these depressions is the Mediterranean sea, as a result of that area's low pressure and the surrounding high pressure areas over the adjacent land. It is also called a western depression, because it moves from west to east.This movement occurs along two main paths, one of them to the north of Kuwait, and the other to the south. The path depends on the strength of the Siberian high pressure. Whenever this system extends to the south the depressions take the southern track, and vice versa (Sharaf, 1980; Al-Kulaib, 1981;1984). In detail these tracks are follows:

a) Northern Track: (Figure 3.6)

The core of this track passes through Syria, Iraq and eastward to Iran. These depressions cause a small amount of rainfall and rising dust or dust storms. The winds are variable and from the south, to south west. As a system moves along this track, the winds shift to the north west (Sharaf,1980; Al-Kulaib 1984).

b) Southern Track: (Figure 3.7)

This track passes north of the Red sea and Arabian peninsula moving eastward, and passing south of Kuwait. It causes more rain than the northern one. The winds blow from the south east or south. The wind direction changes to north east and north after the system passes to the east of Kuwait.

The southern winds give the depression some moisture because they are coming from warm water body of the Arabian Gulf (Al-Kulaib,1984)

2) During Spring: (Figure 3.8)

Spring is a transitional season for pressure systems. High pressure still exists and influences the country, but not as it does in winter. This is because it is weak and divided into small cells as a result of increasing heat over the Asian continent. Low pressure systems start to develop in the south-west of Asia and north west of India due to the increase in radiation (Al-Kulaib, 1980). Also, some thermal lows begin to develop

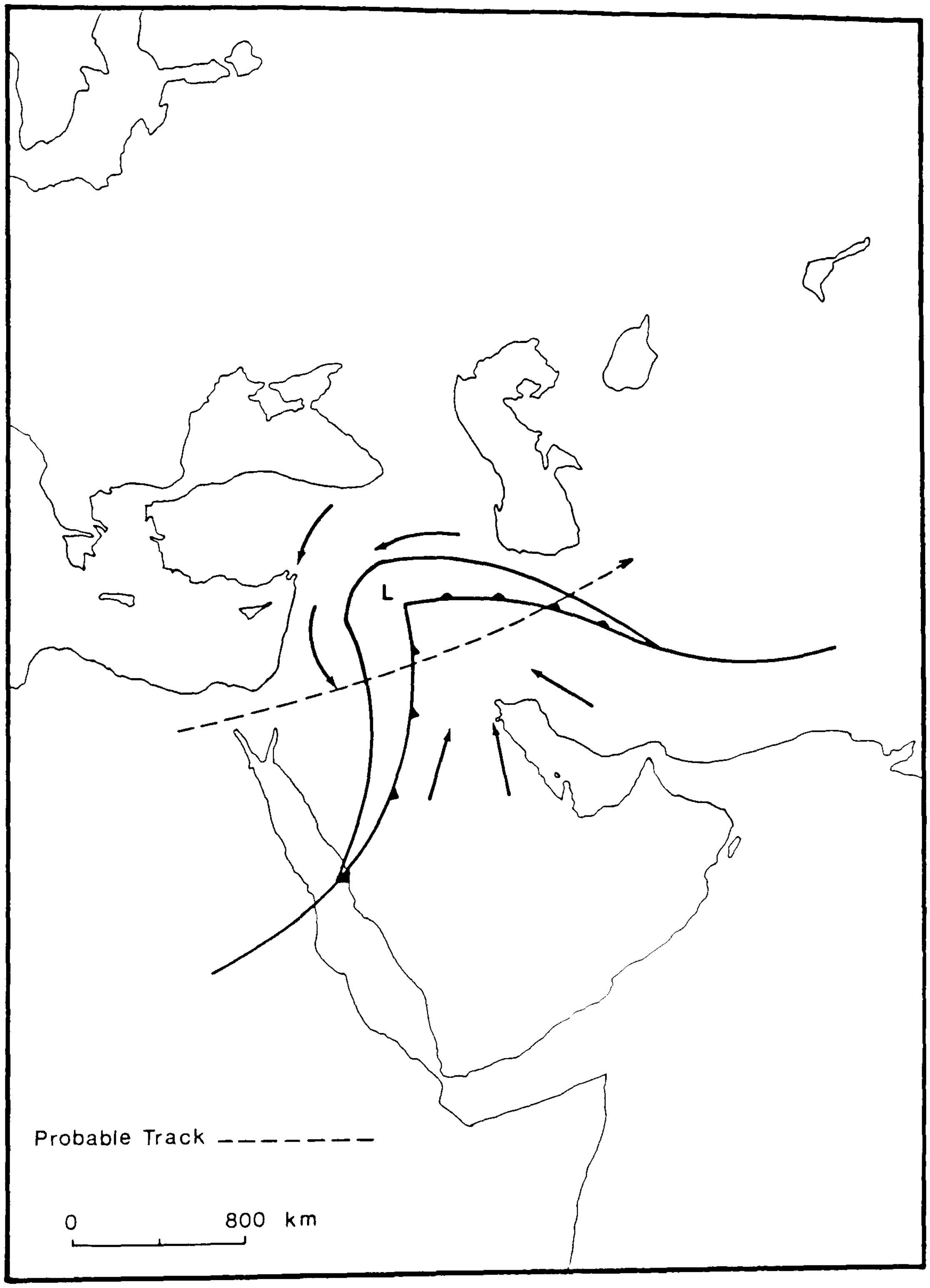


Figure 3-6: The northern track of winter depressions.

(After: Al-Kulaib, p.28, 1984)

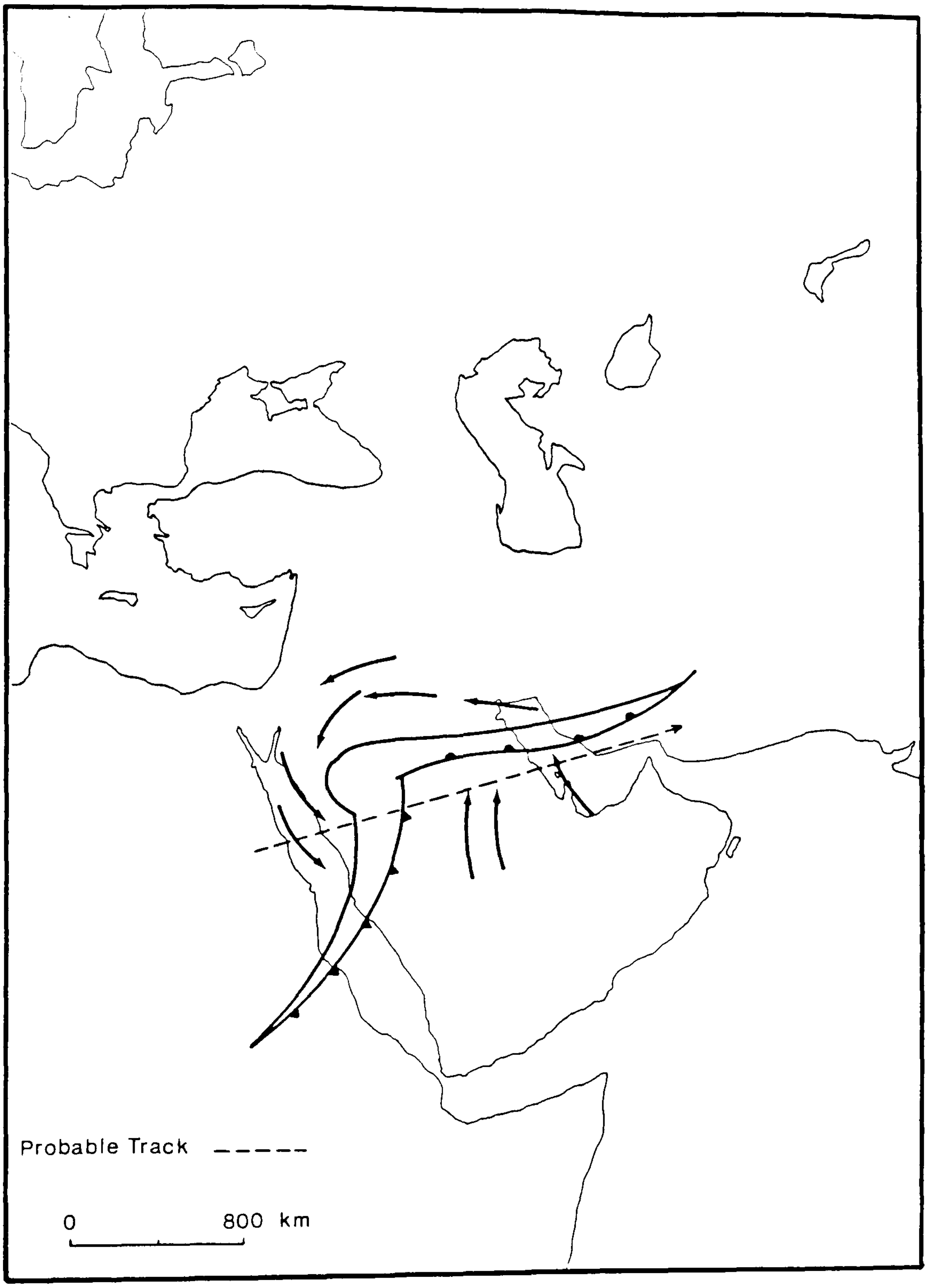


Figure 3-7: The southern track of winter depressions.

(After : Al-Kulaib, p.121, 1984)

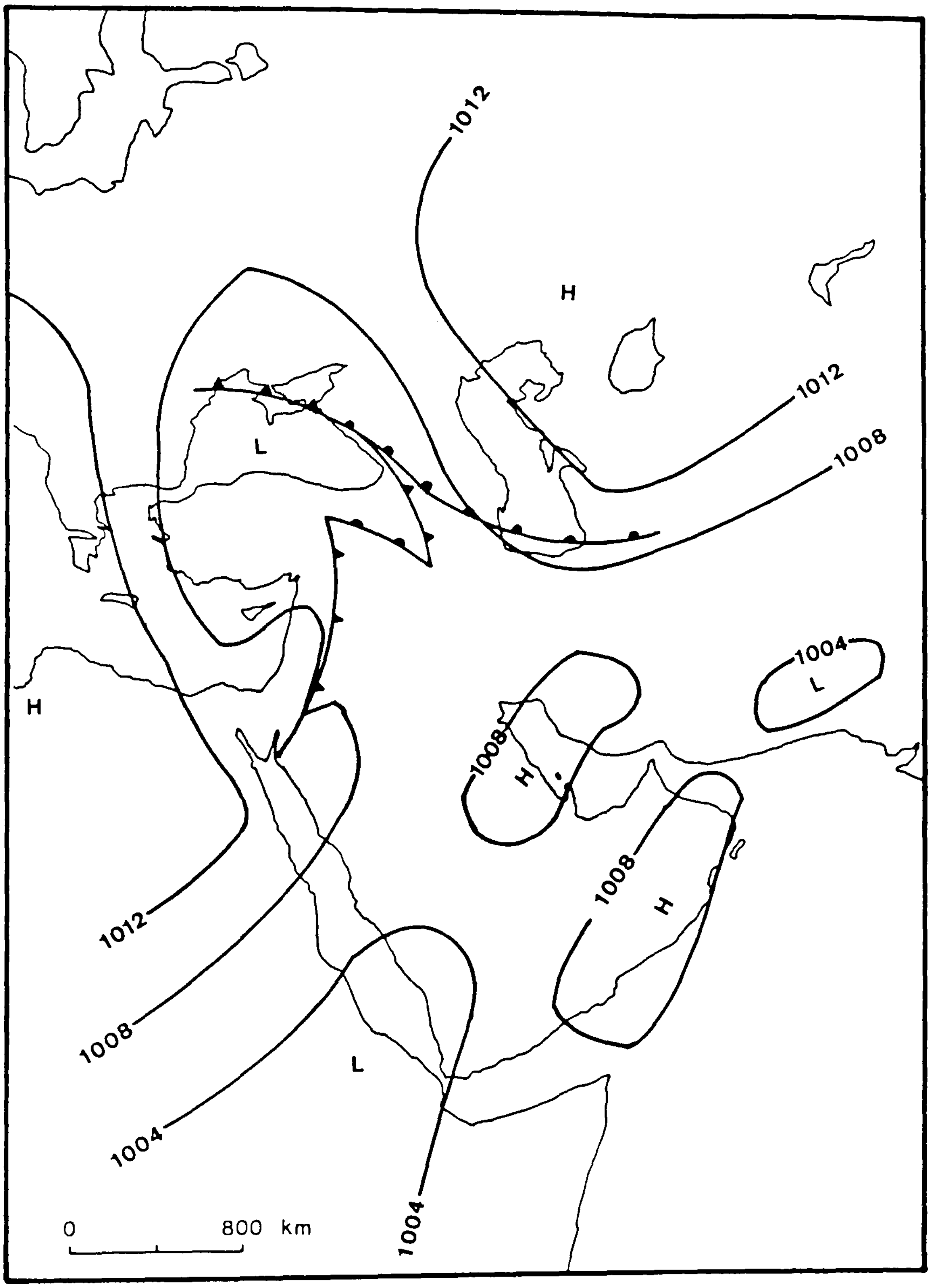


Figure 3-8: Pressure distribution during spring (mb).

(After: Al-Kulaib, p.32, 1984).

due to convection. Therefore, north or north-west winds decrease and south or south-east winds increase (Al-Kulaib, 1980). In the late spring local thunder storms named "Sarrayat" occur. These Sarrayat storms are accompanied by severe dust storms when the visibility can fall to zero. Sometime there are heavy rain showers in these storms (Ministry of Planning, 1986).

3)During Summer:

The summer season is divided into two periods. The first one is the dry

summer (June-July), the second term is the humid summer (August-September).

a)Dry Summer (June-July): (Figure 3.9)

By the end of May low pressure develops and high pressure weakens. This development is due to the large amount of radiation the Asian land receives, and produces the monsoonal low pressure which has its origin over north-west India, and expands over Iran and the Arabian peninsula. The centre of this low pressure is east of Kuwait. Therefore, Kuwait is under the effects of dry, hot and dusty north-westerly winds, which are named locally "Simoom" meaning "poison wind" (Middeton, (A), 1986). This wind is accompanied by dust storms. The wind typically blows for about forty days, and another local name is "Arba'eeneyah" meaning forty (Ministry of Planning, 1986; Al-Kulaib, 1984).

b)Humid Summer (August-September): (Figure 3.10)

By late July, the monsoon low pressure become weak and divides into two main cells located thus: (Al-Kulaib,1981)

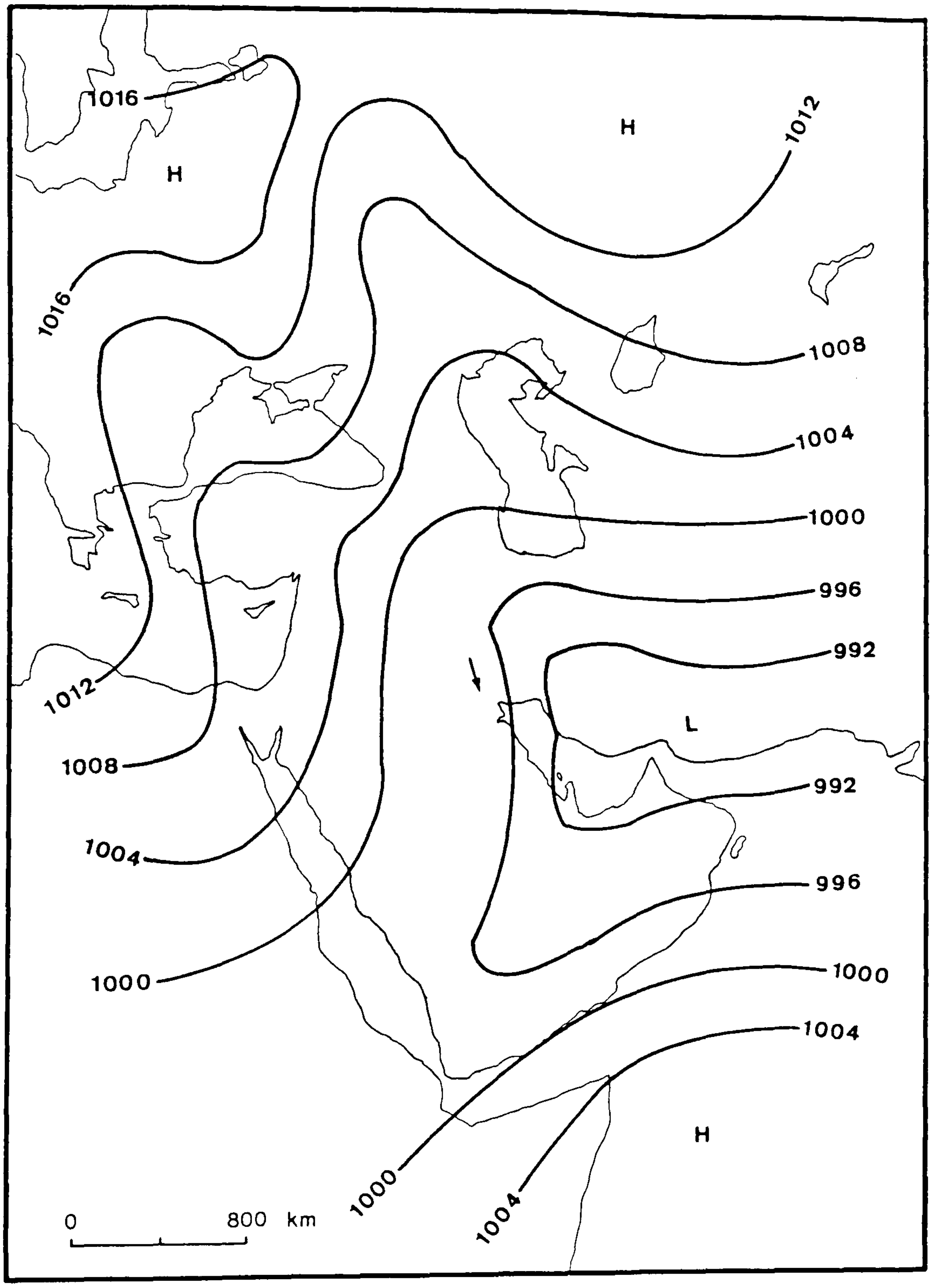


Figure 3-9: Pressure distribution during June and July (mb).

(After: Al-Kulaib, p.34, 1984)

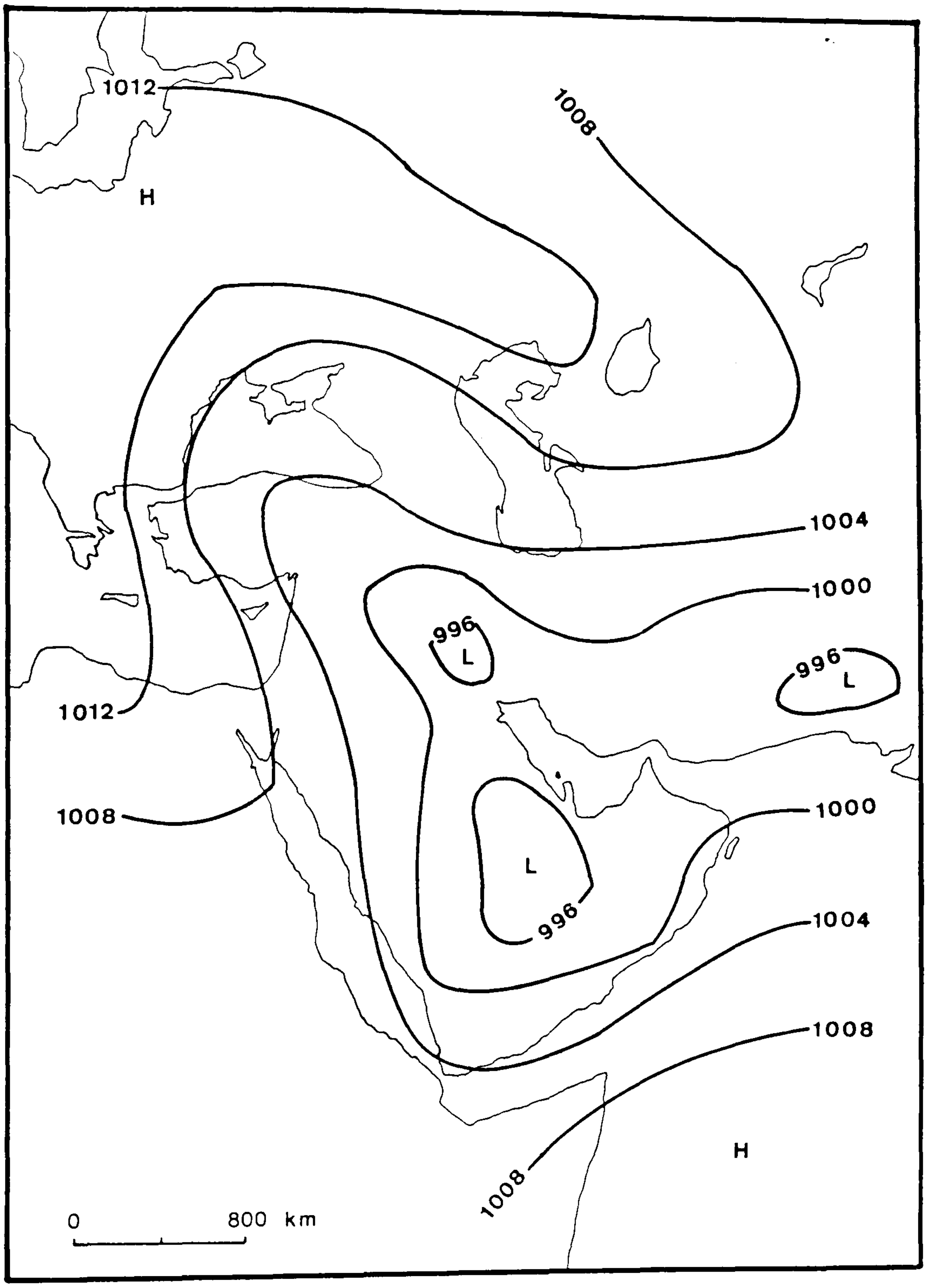


Figure 3-10: The late summer pressure distribution (humid summer) (mb).

(After: Al-Kulaib, p.36, 1984).

a) Over the east of the Arabian Gulf and Iran.

b) Locally over the Arabian peninsula.

There is a high pressure cell over the Caspian sea. In consequence of this pressure distribution, south easterly winds blow over Kuwait. These are hot and humid winds (Al-Kulaib,1980;1984; Ministry of Planning, 1986)

4)During Autumn: (Figure 3.11)

This is the second transitional season. During this season, the low pressure systems weaken and conversely high pressure systems increase because of decreased amounts of heat radiation received. Therefore, the wind direction shifts from the south-east to the north west (Al-Kulaib, 1980; 1984; Ministry of Planning, 1986).

4) Terrain:

Normally terrain has a significant effect on weather elements such as temperature. But, in case of Kuwait, terrain features do not have a significant effect on weather, because the terrain is flat, the highest elevation point being around 300 metres in south western part of Kuwait (Holzer, 1968; Halwagy, (A), 1974; Khalf, Gharib and Al-Hashash,1984; Mohammad,1985). The land surface slopes toward the north east at an average gradient of 1 metre/500 metres (2m./1km.) (Holzer, 1968;Khalaf, Gharib and Al-Hashash, 1984). There are some small coastal hills such as the Jal Az-Zoar which has a maximum elevation of 145 metres, and Al-Ahmadi Ridge which has elevation of 137 metres (Hoolzer, 1968; Khalaf, Gharib and Al-Hashash, 1984; Mohammah,1985). Kuwait has a long coastline along the western Arabian Gulf. Therefore, the eastern winds

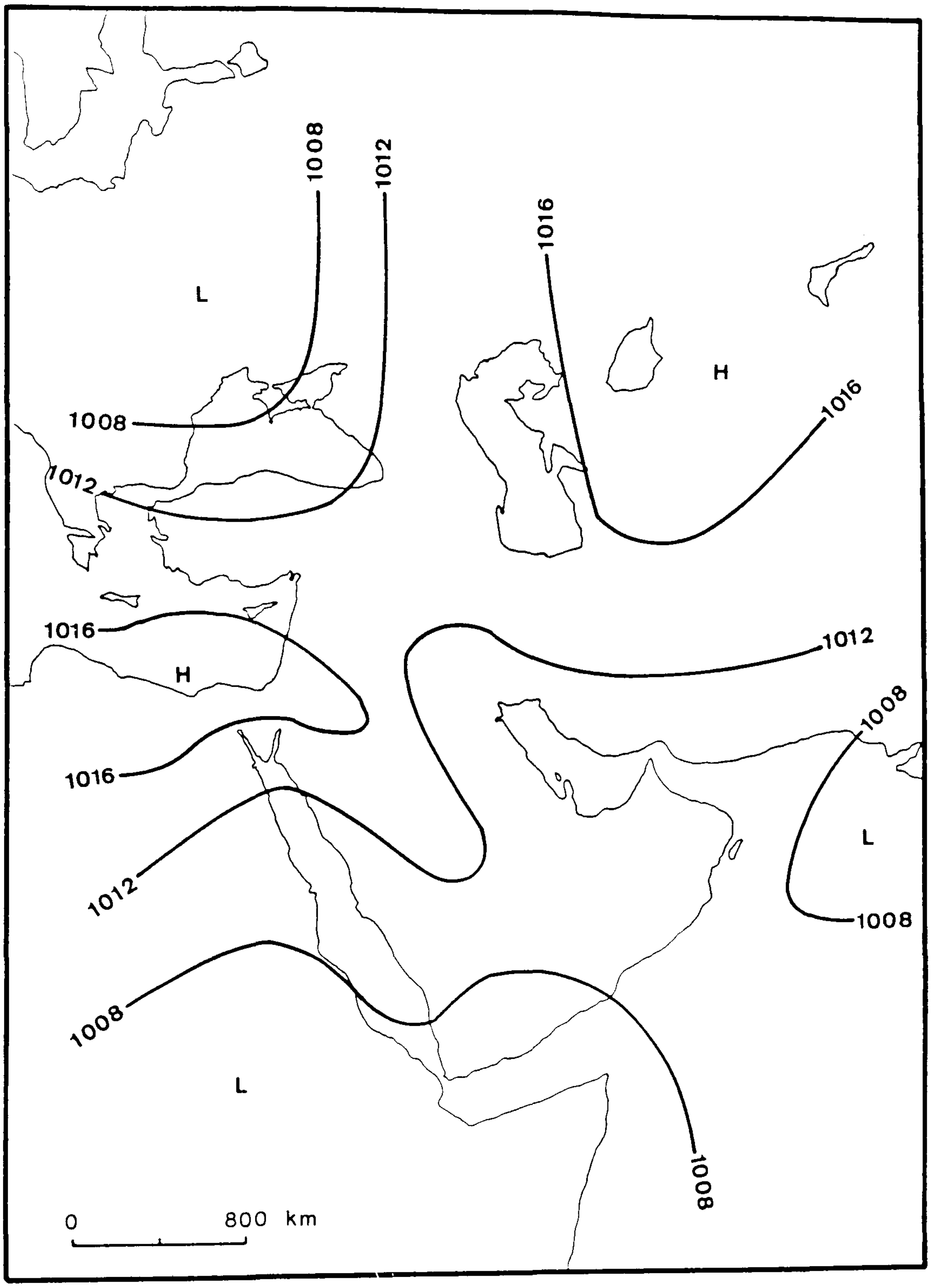


Figure 3-11: The pressure distribution during (October) Autumn (mb). (After: Al-Kulaib, p.39, 1984).

contain a high proportion of moisture brought to Kuwait are somewhat influenced by these low hills. These eastern winds are named "Sharki", which means easterly, or "Kaus" (Keeton, 1928).

CHAPTER FOUR: DUST STORM AND THEIR CHARACTERSTICS

4-1) Introduction:

Dust storms and many other types of suspended dust are common phenomena in the arid and semi-arid regions in the world (Goudie, 1978; Safar, 1985; Middleton, 1986; Grigorgen and Jakondratyer, 1980). This environmental problem is not new, and has been mentioned in the Bible (quoted by Péwé (1981)) "The sun became black as sackcloth of hair ....." Revelation 6:12. Also, it has been described in Sumer (Iraq) by the horticulturist Shakaihtud who wrote in about 3000 B.C. (Quoted by Kramer, 1965 in Nalivkin, p.126, 1986):

"Father, as I filled the furrows with water
As I dug wells in the bed
I tumbled over the roots and they scratched me.
Furious wind all around
And wind with dust enveloped my face
My face .... and my hands
To my garden in five or ten inaccessible places.
In each of these places I planted tree for shelter in the shade
The shelter of the shade of "Sarbat" with which leaves,
The shade that it gives in the morning
And at midday in Summer it never disappears."

Keyes in 1917 (Nalivkin, p.113, 1986) described a dust-storm by comparison with a large river: "A dust or sand storm is as much a

transporting agent as any river. In comparison to a big river it is gigantic in the transportation of deposits. Its width is 300-500 km as compared to the width of 2-3 km of big rivers. It transports at a speed of 60 km/hr as against 5-10 km/hr ....."
"It transports a hundred thousand times more eroded material, a huge quantity of which is from the arid parts of semi-arid and humid regions".

In general this phenomenon is favoured where loose surface material and fresh winds occur. These two conditions are more common in the arid and semi-arid lands (Goudie, 1978; Safar, 1985, Middleton, 1986, Grigoryev and kondratyev, 1980). Arid zones cover roughly one-third of the earth, made up of approximately 4% of extremely arid, 15% arid and 14.6% semi-arid land, comprizing in total about 49 million square kilometres (Goudie and Wilkinson, 1977). Therefore, as is shown by **table 4.1** dust storms and sand storms are common phenomena among the Middle East countries.

Country	% Arid	% Semi-Arid
Afghanistan	40	40
Bahrain	100	-
Egypt	100	-
Iran	65	25
Iraq	70	25
Kuwait	100	-
Lebanon	-	10
North Yemen	50	45
Oman	100	-
Qatar	100	-
Saudi Arabia	95	5
Southern Yemen	100	-
Syria	70	20
Turkey	-	50
United Arab Emirates	100	25

Table 4.1: Percentage of arid and/or semi-arid zones in the Middle East countries. (After: Boules, L., p.130, 1985).

4-2) Definitions:

Before defining a dust and sand storms, it is an important to distinguish between the two, because there is some confusion between these two phenomena. Some people believe that they are one. In fact they are very similar to each other, but there are some differences. The main differences are:**(Plate 4-1 & 4-2)**

1) Particle Size:

Dust storm particles are smaller than sand storm particles. Banoub (1970) suggested that sand storm particles are greater than 100 microns and dust storm particles are smaller than 100 microns

Plate 4-1: Severe summer sand storm, with sand particles crossing the Ahmadi-Maqua road (north-South) and covering the road. This road runs through the Ahmadi desert. The wind is blowing from a north-westerly direction (from left of photo), and the visibility is below one kilometre. The severity of this sand storm is shown by sand particles which are blown through break wind sheltering Ahmadi City (right side of photo).

Plate 4-2: Dust storm day in Kuwait city. The dust cloud covers the sky and visibility is less than one kilometre. The distance between the two lamp posts (on the left) is fifty metres. The dust cloud obscured sun light, as is shown by this picture taken during the middle of a summer's day. Notice the dust deposit on the road curb.

(0.1 mm). But, Lect and Indson (1954) suggested that sand particles range between 0.15 mm and 0.30 mm (150-300 microns) whilst dust particles are smaller than that. The Glossary of Meteorology (1959) considered that sand particles range from 0.08 to 1 mm (80-1000 microns). According to Bagnold's (1935) experiment, most sand grains have diameters between 0.8 and 0.08 mm (800-80 microns).

2) Vertical Motions:

Because dust storms have finer particle content than sand storms, the dust particles comprizing the former are easily lifted into the air. Dust particles are swept upward hundreds of metres above the ground, but sand particles move forward in a series of jumps a few metres or less above the ground. This process is called saltation (Tarbuck and Lutgens, 1984; Lect and Judson, 1954). Generally sand storm particles rarely rise more than fifty feet (15.2 metres) above the ground (Huschke, 1959; Glossary of Meteorology).

Cole (1938) defined a dust storm as an obscuration due to sand or dust, with a wind of Beaufort force 4 or over, causing a decrease of visibility to below 1000 metres.

The Penguin Dictionary of Physical Geography (p.158,1984) defines a dust storm as: "a storm in arid or semi-arid regions in which the immense volume of dust whipped up by the wind brings a serious reduction of visibility, sometimes to zero". The Glossary of Meteorology (p.183, 1959) defines dust storms as:" An unusual, frequently severe weather condition characterized by strong winds and dust-filled air over an extensive area. Prerequisite to a dust storm is a period of drought over an area of normally arable (sic) land, thus providing the very fine particles of dust which distinguish it from the more common sand storms of desert regions. A dust storm usually arrives suddenly in the form of an advancing dust wall which be miles long and several thousand feet in height, ahead of which there may be some dust whirls, either detached or merging with the main mass. Ahead of the dust wall the air is very hot and the wind is light.

In the United States weather observing practice, if blowing dust reduces visibility to between $5/8$ and $5/10$ statute mile (1000-800 metres), a 'dust storm' is reported; if the visibility is reduced to below $5/16$ statute mile (500 metres), it is reported as a "severe dust storm"". Also, the Glossary of Meteorology (p.491,1959) defines the sand storm as: " a strong wind carrying sand through the air, the diameter of most of the particles ranging from 0.08 to 1mm (80-1000 microns)". "Sand storms are best developed in desert regions where there is loose sand, often in sand dunes , without much admixture of dust".

The most common dusty wind blowing over Kuwait are Shamal and Simoom. Shamal is described by the Glossary of Meteorology (p.505,1959) as " the northwest wind in the lower valley of the Tigris and Euphrates and the Persian Gulf. It may set in suddenly at any time, and generally lasts from one to five days, dying down at night and freshening again by day; but in June and early July it continues almost without cessation (the great or "forty day" Shamal). Although the wind rarely exceeds 30 mph, it is very hot, dry and dusty. The sky is cloudless but the haze is often so thick as to obscure the land, making navigation dangerous".

Simoom is defined in the Glossary of Meteorology (p.511,1959) as " a strong, dry, dust-laden desert wind which blows in the Sahara, Palestine, Syria and the desert of Arabia. Its temperature may exceed 130°F (54°C) and the humidity may fall below 10 per cent. The name means "Poison Wind" and is given because the sudden onset of a simoon may cause heat stroke. This is attributed to the fact that the hot wind brings more heat to the body than can be disposed of by the evaporation of perspiration".

It is noticeable that the local names do not distinguish between the dust storms and sand storms. Also, it is noteworthy that it is agreed internationally, whenever the visibility is reduced by dust or sand and is less than 1000 metres this is reported as a dust storm day (Idso, 1976; Safar, 1985; Al-Kulaib, 1984; Loeme, 1943; Coles, 1938; Middleton, Goudie and Wells, in Nickling (ed), 1986).

It should be borne in mind that there are other types of dust which reduce the visibility to less than 1000 metres or to zero in some cases, such as thick haze. In this latter case the lower wind velocity is the main distinguishing between them. Also, there are other phenomena beside dust types affecting the visibility, including fog and rain (Middleton, Goudie and Wells, in Nickling (ed), 1986).

4-3) Classification:

Many classifications of dust storm have been proposed. Generally, each of these classifications have been used to serve the purpose of scientific study. Therefore, these classifications vary depending on the view which the particular scientist involved. In most of these classifications the visibility is the major consideration. Some examples of these classifications follow :

1) Visibility: (Plate 4-3.a& b) Oliver (1945) examined dust storm in Egypt during World War Two. He divided dust storms into two types:

a) Very Severe Dust Storm: when visibility is 50 metres or less.

b) Severe Dust Storm: when visibility is between 50-200 metres. Al-Kulonib (1984) used the same approach as Oliver but also considered wind origins.

a) Severe dust storm: when the visibility is less than 200 metres due to

Plate 4-3.a: During a clear day on As Safer Motorway, the road sign and building in Riqqa city are clear. These buildings are about one kilometre distant.

Plate 4-3.b: Summer dust storm day, same view of plate 4-7.a, where the visibility is less than one kilometre. The buildings visible in plate 4-7.a have disappeared from view due to dust storm. The dust storm is blowing from a north westerly direction (from right side of plate to left). The road sign is not very clear due to the presence of suspended dust particles in air, even though it is only a short distance from the point where the photograph was taken.

local wind.

<u>b) Moderate dust storm:</u> when the visibility ranges between 200-1000 metres due to local winds.

<u>c) Moderate Rising Dust:</u> when the visibility ranges between 1000 metres and 5 km due to local winds.

<u>d) Slight Rising Dust:</u> when the visibility becomes equal to or more than 5 km due to local winds.

<u>e) Thick Suspended Dust:</u> when the visibility becomes less than 1000 metres due to dust not raised by local winds.

<u>f) Moderate Suspended Dust:</u> when the visibility is more than 1600 metres and less than 5 km. and in which the dust is not raised by local winds.

<u>g) Haze :</u> when the visibility becomes equal to or more than 5 km due to haze.

<u>2) Duration :</u> Romanov (1961) proposed the following scheme. This classification is based on duration of dust storms from observations in Central Asia and was developed for aviation purposes. Romanov divided dust storms as follows: (Nalivkin,p113, 1986):

a) Short-lived dust storm with reduction in visibility, duration is of a few minutes

b) Short-lived dust storm with reduction in visibility, duration is from few minutes to ten minutes. The clouds of dust are dense, grey and of different heights.

c) Long-lived and pulsating storm with reduction in visibility, duration is from a few hours to a few days.

d) Strong prolonged storm with reduction in visibility, prolonged duration from 2-4 hours to a few days.

3) Colour and Composition: Zhukov (1964) produced a classification based on colour and composition of dust storms. This classification is relevant for geologists (Nalivkin,p114, 1986):

a) Dark Storm: the name comes from the black soil of agricultural regions which was carried by this storm.

b) Yellow Storm: the colour is due to yellow sand and dust, which is common over desert area

c) Red Storm: this is so named because this storm runs over the area where there is red sand and dust. The red colour is due to iron oxide.

d) White Storm: this type of storm appears over broad salt zones; salt gives the white colour.

4) Seasonally: In this case dust types are divided according to the time of year. Coles (1938) classified dust storms in Iraq:

1) Winter Storms

2) Summer Storms

5) Visibility and Wind Type : Warn (p.241,1952) classified dust storm in the southern High Plains of the United States as set out in the following table:**(Table 4.2)**

Type No.	Intensity	Usual Duration hours	Max.Horiz. Wind Speed (mph)	Max.Height Dust (ft.Above the ground	Horizontal Visibility (miles)
1	Light	0.5-0.3	14-24.9	500	8-15
2	Mild	1/2-3	25 - 34	5,000	2-7
5	Moderate	1-6	35-44	12,000	3/4-2
7	Strong	3-12	45-54	18,000	1/4-3/4
9	Severe	6-24	55-65	30,000	0-1/4

Table 4-2: Classification of blowing Dust. (After: Warn, p.241, 1952)

This table is based on 110 observations of dust storms during the period of 1949-50.

Safar (1985) divided dust storm in Kuwait into four categories:

a) Dust/Sand Storm: the winds are fresh or strong (about 18 knots or more), and the visibility is less than 1000 metres **(Plate 4-4)**. Whenever the visibility drops below 200 metres, it is considered as severe dust/sand storm **(Figure 4-1)**.

b) Rising Dust: winds are moderate, and the visibility is equal to or more than 1000 metres.

c) Suspended Dust: the winds are light or calm. The visibility is less than 100 metres in case of thick suspended dust, but when dust is not raised by local winds, the visibility ranges between 1 km and 5 km.

d) Haze: it is composed of small solid particles of dust, smoke or salt, and the visibility is equal to, or more than 5 km.

4-4) Classification of Dust Storm in Kuwait:

Dust storms are common phenomena in Kuwait. They may exist at any time and in any month. Therefore, for a dust storm classification in Kuwait, the following should be considered :

1) Dust is present in the Kuwait air most of the time, from January to December. But, it is more frequent in summer time than any time of the year **(Table 4.3)**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec.
47.9	60.9	65.7	70.7	79.4	87.2	82.3	78.2	75.3	67.1	57.1	52.0

Table 4.3: Monthly percentage of dusty days (all dust types) in Kuwait from 1962 to 1986.

Plate 4-4: Severe dust storm day on the As Safer Motorway where the visibility has dropped to less than five hundred metres; two light posts clearly seen but a third one is not shown because of poor visibilty. The road sign (on the left) is not clear, and this may be a hazard to moving traffic. This picture been taken during mid day in summer (about 10.30 am).

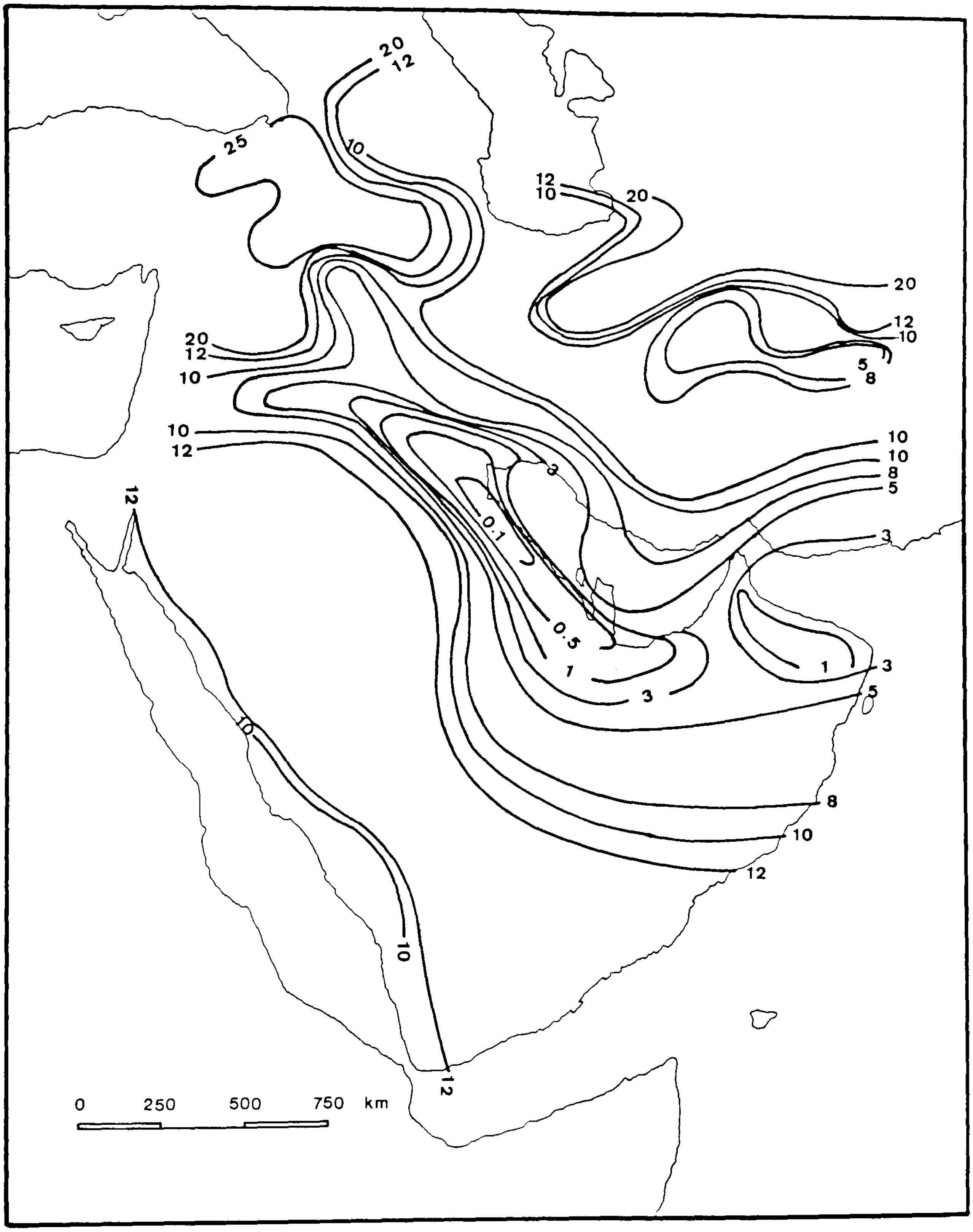


Figure 4-1: Distribution of poor visibility which occurs in the area as a result of summer dust stroms (in kilometres).

(After: Al-Kulaib, p.103, 1984)

2) More than one type of dust is likly to occur in Kuwait during any one season (Safar, 1985; Al-Kulaib, 1984).

3) The data of weather observations in Kuwait which are issued by Climatological Department in Kuwait International Airport, divide dust storm observations into the following categories:

a) Dust Storm

b) Rising Dust

c) Suspended Dust

d) Haze

1) Sand/Dust Storms: (Plate 4-5)

These are the storms which are associated with fresh or strong local winds of 18 knots (9.25 m/s) or more. Visibility is less than 1000 metres (Safar, 1985; 1982, Al-Kulaib, 1984; Banoub, 1970; Loewe, 1943; Climatological Summaries, 1983). Whenever the visibility drops to below 200 metres it is recorded as a severe sand/dust storm (Safar,. 1985; 1982; Al-Kulaib, 1984; Oliver, 1945; Climatological Summaries, 1983). The main wind direction during the dust storm blows is from the north-west **(Table 4.4)** (Safar, 1985; Al-Kulaib, 1984).

Lowest visib. (km)	Mean Wind Speed (m/s)	% of Dusty Winds Direction							
		N	NE	E	SE	S	SW	W	NW
Max. 0.9	11.8	6.1	2.4	8.9	12.3	6.8	3.1	6.5	53.9
Aver. 0.42	7.4								
Min. 0.0	2								

Table 4.4: Dust storm lowest visibility (km), mean wind speed (m/s) together with dust and percentage of dusty winds directions in Kuwait from 1975-1986.

Plate 4-5: Severe July sand storm day, in which visibility range has dropped to less than five hundred metres. The barrels (on right of photo) distance are at about thirty metres distant. This type of severe sand storm badly affects drivers especially those working in the desert, in oil production. In these circumstances there is a strong predisposition for the occurrence of road accidents especially on two-way-road like Ahamdi-Maqua road. The edge of road is covered by sand deposit.

Dust storms are more common in the summer time than at any other time of the year in Kuwait (Safar,1982; 1985; Sharaf,1980; Al-Kulaib,1984). The highest cumulative monthly numbers of dust storm days from 1962 to 1986 (25 years) was June 118 days, July 108 days and May 100 days. On the other hand, the lowest cumulative numbers of dust storm days are in November 10 days; September 16 days, January 26 days and December, 27 days **(Table 4.5)**.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec.
3.4	4.6	6.6	10.3	13.3	15.7	14.4	7	2	4.7	1.4	3.5

Table 4.5: Percentage of days per month with dust storm occurrence in Kuwait (1962-1986).

2) Rising Dust:

This is dust which rises with local moderate winds. Rising dust is counted as moderate whenever the visibility ranges between 1000 metres to less than 5 km. Whenever visibility improves and become equal to or greater than 5 km, this is reported as slight rising dust (Safar, 1982; 1985; Al-Kulaib, 1984; Climatological Summaries, 1983). The main direction of wind during rising dust is from the north west, with average of mean wind speed at 6.3 m/s **(Table 4.6)**.

Lowest visib. (km)	Mean Wind Speed (m/s)	% of Dusty Winds Direction							
		N	NE	E	SE	S	SW	W	NW
Max. 12	10.7	8.8	0.8	5.3	10.9	5.9	0.7	12	55.6
Aver. 3.3	6.3								
Min. 0.05	1.7								

Table 4.6: Rising dust lowest visibility (km), mean wind speed (m/s) and percentage of rising dust wind directions in Kuwait from 1975 to 1986.

Like dust storms, rising dust is concentrated in the summer months. During the period of 1962 to 1986, the highest total of rising dust days were in June 260 days, July 210 days and August 202 days. The lowest totals of rising dust days are November, 71 days, January, 84 days and December 85 days **(Table 4.7)**.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec.
11	15.6	20.1	21.1	35	27.1	26.2	16.2	16.4	11.4	9.3	10.9

Table 4.7: Percentage of days per month with rising dust occurrence in Kuwait (1962 1986).

3) Suspended Dust:

Generally this is associated with light or calm winds. In composition its particles are smaller than those of dust storms and rising dust.
It is noteworthy that this type of dust is not raised by local winds, since the light winds which usually occur on occasions of suspended dust are

unable to lift up dust particles in the air. Whenever the visibility range drops below 1000 metres, it counts as thick suspended dust, and whenever the range becomes 1000 metres to less than 5 km it counts as moderate suspended dust (Safar, 1982; 1985; Al-Kulaib, 1984; Climatological Summaries, 1983). The main wind directions associated with suspended dust are north-west, east and north **(Table 4.8)**.

Lowest visib. (km)	Mean Wind Speed (m/s)	% of Dusty Winds Direction							
		N	NE	E	SE	S	SW	W	NW
Max. 8	8.9	14.4	3.8	17.4	7.4	13	0.5	8.7	34.8
Aver. 2.9	3.4								
Min. 0.0	0.2								

Table 4.8: Suspended dust lowest visibility (km) mean wind speed (m/s) and percentage of dusty winds direction in Kuwait (1975-1986).

The maximum monthly totals of suspended dust days for the period of 1962 to 1986 were May 156 days, September 140 days, July 137 days and October 132 days. The minimum total number of suspended dust days were January 71 days, and December 74 days **(Table 4.9)**.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec.
9.3	14.4	15.7	16	20.2	15.6	18	16.4	19.4	17.5	13.3	9.5

Table 4.9: Percentage of days per month with suspended dust occurrence in Kuwait (1962-1986).

4. Haze:

This is composed of very fine particles of dust, smoke or salt. Horizontal visibility is generally as being equal to or more than 5 km. (Safar, 1982; 1984; Al-Kulaib, 1984; Climatological Summaries, 1983). Whenever the visibility is reduced to less than 1000 metres it is counted as thick haze or thick suspended dust (Al-Kuliab, 1981). The particle size is so fine, less than 1 micron, that it does not fall on the ground under gravity (Al-Kuliab, 1981). The main winds associated with haze is like the other dust types from the northwest **(Table 4.10)**.

Lowest visib. (km)	Mean Wind Speed (m/s)	% of Dusty Winds Direction							
		N	NE	E	SE	S	SW	W	NW
Max. 9	7.2	13.7	2.5	16.4	6.1	14.1	-	12.2	35
Aver. 5.7	3.1								
Min. 0.0	0.09								

Table 4.10: Haze lowest visibility(km), mean wind speed(m/s) and percentage of dusty wind directions of haze in Kuwait (1975-1986).

4.5) Dust Sources:

World wide the main sources of dust are from dry, loose sandy and unvegetated lands. It is not necessary for dust or haze present in the air to be from local sources (Middleton, 1986). In many cases the dust has been transported to the region from source areas which may be far away. Some of the Saharan dust has been found in America (Péwé, 1981; Goudie, 1983). Many regional dust sources have been identified including following (Idso, 1976; Goudie, 1983; Péwé, 1981; Middleton,(A)

1986):

1) Central and western Africa (Sahara)

2) The southern coast of the Mediterranean

3) North-eastern Sudan

4) The Arabian Peninsula

5) The lowest Volga and North Caucasus in U.S.S.R.

6) The north and western part of China (Gobi).

7) Central Australia

8) The south west United States (southern Great Plains)

9) The Kalahari Desert of South West Africa

10) North-west of India, the alluvial area of Rajasthan and neighbouring states

11) Afghanistan, in Kandahar on the edge of the Registan Desert

12) Chile

13) Peru

14) The drier parts of Argentina

The major region of the dust production is the huge desert belt which extends from the west coast of Africa, eastward to the north west of China (Middleton, Goudie, Wells, in Nickling (ed), 1986). It is noteworthy that with regards to sources of dust in the world :

1) Most of these sources are concentrated in the north hemisphere

2) Most of the dust sources are located in Africa and Asia

3) Most of these sources are located between 20° to 35° north and south of the equator.

4.6) Main Dust Sources of Kuwait:

Kuwait is part of the great desert belt noted above and part of one of the major dust source area, the Arabian Peninsula. Besides this major dust source there are further local and regional sources within a radius of about 1000 km. These main sources of the dust which surround Kuwait are **(Figure 4.2)** :

<u>1) The An Nafud, Ad Dahna and Rub Al-Khali:</u> These three deserts are part of the Arabian Peninsula. The An Nafud desert occupies the north-western part, the Ad Dahna the eastern part and Rub Al Khali (Empty Quarter) the southern part of Arabian Peninsula (Al-Guname, 1981). These three deserts together cover an area of about 300,000 square miles(777,000 sq.km). The Rub Al Khali alone occupies about 230,000 square miles(595,700 sq.km) (Holm, 1960) and both An Nafud and Ad Dahna covered about 70,000 square miles(181,300 sq.km) of Arabian Peninsula. The An Nafud and Ad Dahna deserts are closer to Kuwait than Rub Al Khali and therefore have more influence on the occurrence of dust storms in Kuwait than the Rub Al Khali.

<u>2) The Western Iraqi Deserts:</u> The western part of Iraq is occupied by desert. It is a continuation of the eastern part of the Badiet Sham (Syrian Desert) which is part of the Arabian Shield (Thalen, 1979). The western Iraqi desert is divided into two main areas: (Thalen, 1979)

a) Western desert

b) Southern desert

The two deserts occupy about one third to one half of Iraq (Thalen, 19079). Both deserts are sparsely covered with low shrubs and a few perennial grasses and after the rain ephemeral vegetation grows. The two deserts are divided into smaller zones as follow (Thalen, 1979) **(Figure 4.3)**:

<u>a) Dibdibba Plain:</u> Lies in the south eastern part of the southern desert. This plain extends over Saudi Arabia, Kuwait and Iraq. It has a sandy and gravelly surface.

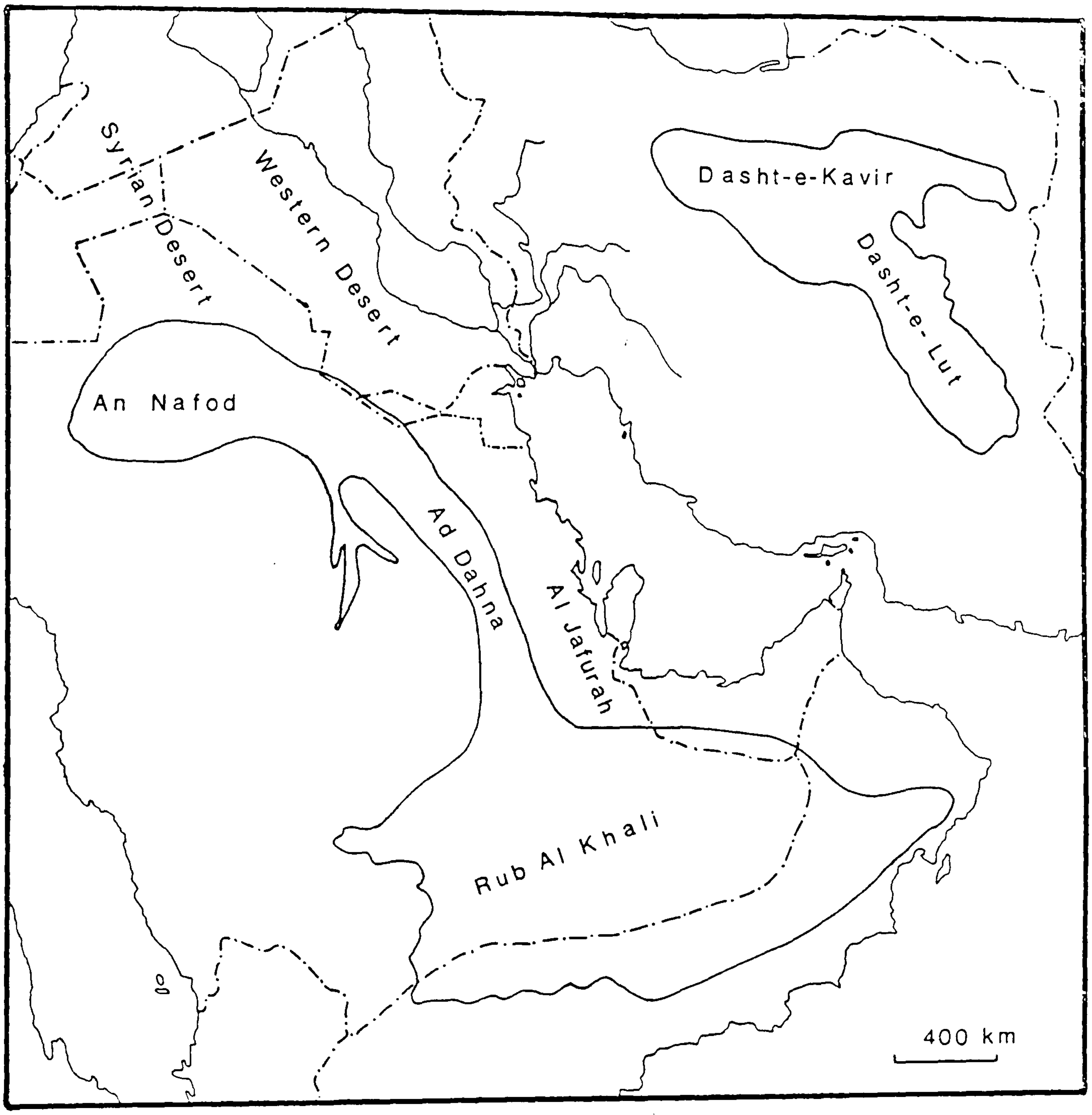


Figure 4-2: Main deserts which surround Kuwait and are considered regional dust sources.

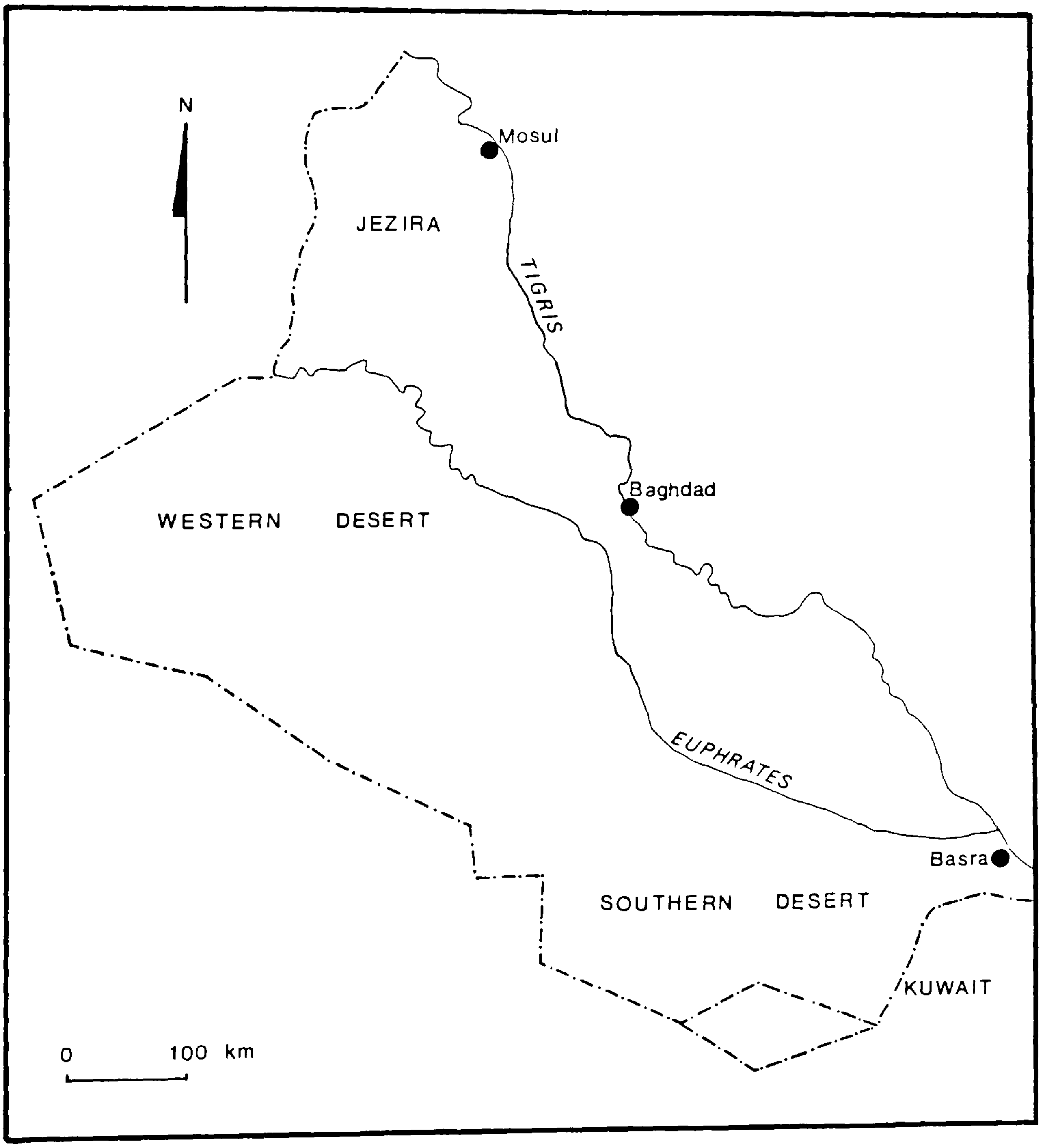


Figure 4-3: Main dust sources of Iraqi Western Desert.

(After: Thalen, p.68, 1979)

b) Al-Hajara Stony Plain: Extends through both the western and southern deserts. There are several important wadis running across this plain; Wadis including the Al-Khir, Ubaiyidh, Ghadef and Hauran. It has a sharp, stony surface.

c) Upper Wadian: Lies on the western side of Al-Hajara Plain. It is part of the Western desert. This area in generally underlain by beds of limestone and sandstone. It is a transition area between the lower Euphrates in the east and Syria and Jordan in the west. Generally the surface of this area is hard and stony.

d) Lower Wadian: Lies parallel to the Al-Hajara Plain, in the eastern side. The underlying strata consists mainly of limestone with some marls and siltstones.

e) Al-Hamam Plain: This plain extends from Iraq through Syria, Jordan and Saudi Arabia. It is an almost featureless stony desert.

f) Euphrates Sand-belt and Ar Rahab: These are the largest sand dune zones of the Iraqi deserts. They run parallel to the Euphrates River on its western side. The Euphrates sand-belt and Ar Rahab are about 270 km long.

g) Jezira Plains: There are on the north of the lower Wadian. The Jezira Plains surface is covered by beds of sand, silt, clays, gypsum and limestone.

3) The Lower Mesopotamian Plain: The term Mesopotamia means between the rivers, from the Greek word "meso" means between and "potamos" means rivers (Stamp, 1957). The lower Mesopotamian plain, which is south of Baghdad, is flat and slopes gradually towards the Gulf. As Fisher (1950) described it: "...the whole area is extremely flat, with a fall of only one inch per mile over the last 100 miles of the Euphrates, and about two inches per mile along the Tigris". Therefore, deposition will be high. The main character of soil in this area is fine fertile alluvium. It becomes a powdery dust during the dry season (summer) and muddy during the wet season (winter) (Stamp, 1957). The flood season is Spring (Fisher, 1950). This area, therefore, can be counted as one of the dust supplier areas during the dry season.

4) Iranian Deserts: There are two main deserts which occupy the Iranian Plateau. There are:

a) Dasht-e-Kavir; and

b) Dasht-e-lut.

According to English-Persian dictionary, the word "dasht" in Persian language means plain or flat land, and Kavir or Kaveer means desert or brackish ground (Hain, 1983).

The area of the Dasht-e-Kavir area is about 67,000 square miles(173,530 sq.km) and of the Dasht-e-Lut is about 30,000 square miles(77,700 sq.km) (Cressey, 1963). The amount of rain is small. For example, the annual rainfall average of some stations around Dasht-e-Lut are Kerman, 118 mm, Bam 43 mm, Zahedan 78 mm and Zabol 45 mm (Kardavni, 1980). These deserts are partly sandy, partly stony, and partly glutinous marsh covered by crusts of salt. In these marshes, man and animals can disappear (Longrigg, 1970). In the past, probably during late Tertiary and early Quaternary the area was occupied by lakes, which have left thick deposits of alluvial material (Fisher, 1961). Fortunately, the Iranian deserts do not have a strong involvement in dust supply to Kuwait, because the Zagros mountain range protects Kuwait from dust transport. Also, the Arabian Gulf plays some role in reducing the amount of dust reaching Kuwait from Iran.

In conclusion, the most important regions of dust production for Kuwait are the deserts of Iraq and the Arabian Peninsula .

4.7) Local Dust/Sand Sources:

Arid and semi-arid zones are strongly affected by the aeolian processes due to lack of vegetation cover, and therefore, a continuous interaction between the wind and surface deposits occurs (Khalaf, Gharib, and Al-Hashash, 1984). Kuwait is located in the dry hot desert zone (BWh) according to Köppen's classification, which means that Kuwait is part of the above mentioned arid region, the surface of which consists mainly of sandy materials, and it is surrounded by sandy and dusty zones such as the Iraq and Arabian deserts. All of these play a major role in supplying the dust and sand to such storms which affect Kuwait (Khalaf, Gharib,and Al-Hashash, 1984; Khalof et al., 1982; Fuchs,and Gattiner, 1968). Beside these regional sources, there are some local ones. Generally, the surface of Kuwait is covered by aeolian mobile sands (Khalaf et al. 1982). The main physiographic areas of Kuwait are shown on **figure 4.4** (Khalaf et al. 1982; Khalaf et al., 1984; Foda,and Al-Attiah, 1982) :

1) The Al-Huwaimliyah Sand Sheet: This sand sheet zone occupies the north western part of the country. There are some barchan sand dunes in the area which are parallel to the Wadi Al-Batin. The average width of these barchans is 20 metres and their height 2 metres. Average grain size is about 0.21 mm, and about 70% of these sand dunes are composed of quartz (Khalaf, Gharib, El-Sayed, Al-Hashash and Al-Kadi, 1982; Kelo and Al-Sheikh, 1986; Khalaf, Ghorib and Al-Hashash, 1984). These sand dunes are perpendicular to the north westerly winds, and therefore, dust and sand movements are associated with the north

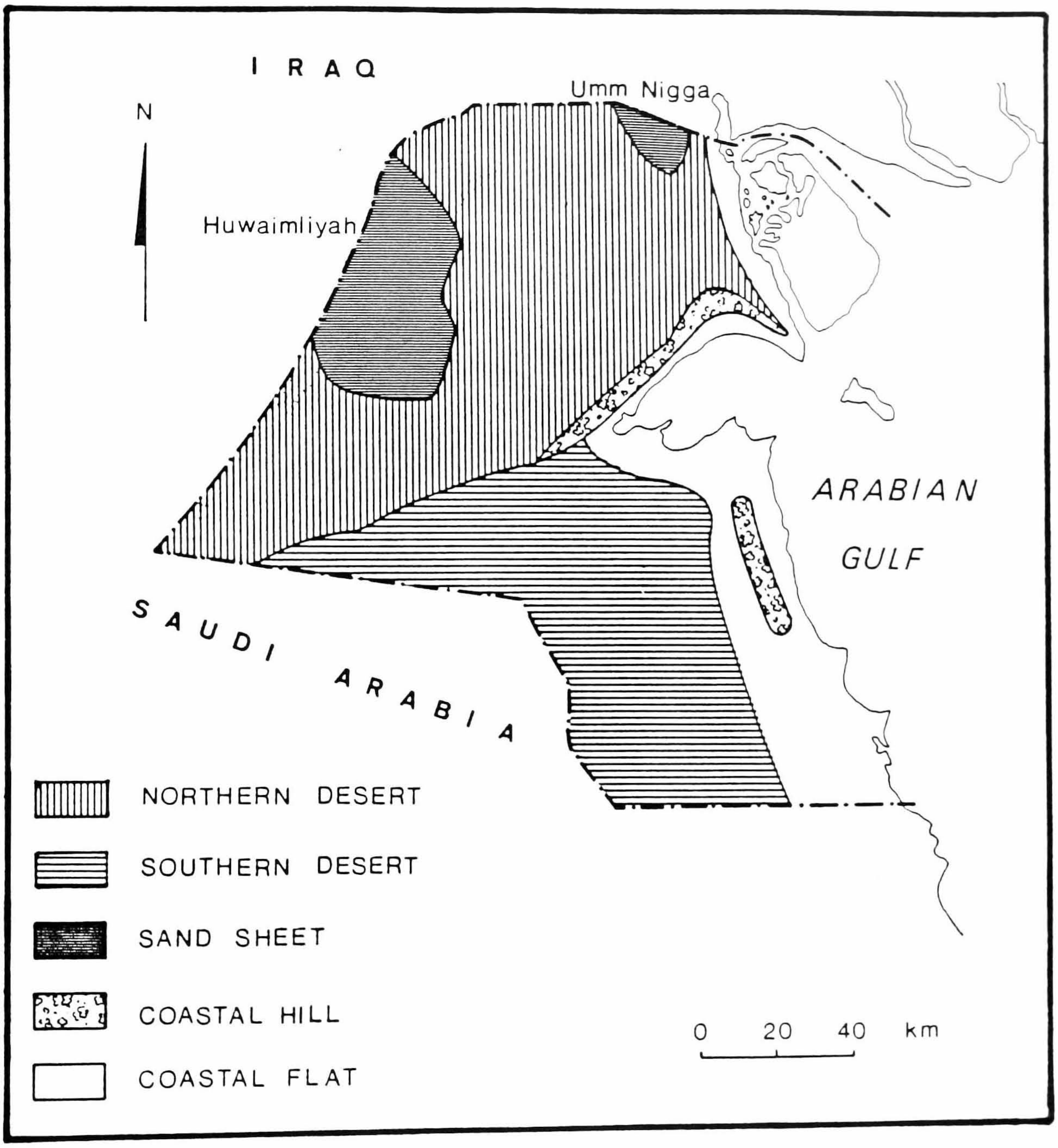


Figure 4-4: Physiographic regions of Kuwait and main local dust sources.

(Modified, after: Kalaf, Gharib and Al-Hashash, p.11, 1984) westerly winds. This area includes the sand belt which is regarded as the main supplier of mobile sand to Kuwait. The sand belt enters Kuwait from Iraq through the Al-Huwaimliyah area and the annual amount of sand which passes through this area is about 175,000 m^3/yr (Foda, Gharib, and Al-Hashash, 1983).

2) The Umm Negga Sand Sheet: is located in the north-eastern corner of Kuwait, and is an extension of southern Iraqi desert (Khalaf, Gharib and Al-Hashash, 1984). There are some sand dunes scattered in the area. Their average width is about 170 metres and average height 8 metres. The average of grain size is also bigger than that of Al-Huwaimliyah of about 0.30 mm and the quartz percentage is higher than Al-Huwaimliyah at about 77% (Khalaf, Gharib, El-Sayed, Al-Hashash and Al-Kadi, 1982).

3) The Southern Coast Area: This area extends from Mina (port) Abdullah to the southern border with Saudi Arabia (Khalaf, Al-Kadi, Garib and Al-Hashash, 1982). This area is one of the most mobile sand areas in Kuwait. The amount of sand which is transported from this area to the southern Kuwait desert is about 139,890 m^3/yr. Conversely the amount of sand which comes to the area from the desert is about 271,330 m^3/yr (Foda, Gharib and Al-Hashash, 1983). This movement is due to the effects of the north-westerly winds.

Coastal dunes occur in this area as a continuous belt, the width and length of which varies from place to place. It is about 3-5 km wide near Ras Az-Zor reducing to 100 metres in Ad-Dhubaiyah. Also, the dune length ranges from about 4 km near Ras Az-Zor to about 250 metres near Al-Khiran. These coastal sand dunes are composed of 92.5% sand and 7.5% silt and clay (Al-Bakri, Shublaq, Al-Sheikh, Kittanch and Al-Ghadban, 1982).

The Sabkhe flat which is developed between the Ras Az Zor and Al-Khiran is composed of muddy sand with an average mud content of about 50% (Al-Bakri, Shaiblaq, Al-Sheikh, Kittanch and Al-Ghadban, 1982).

Besides these three main local sand and dust sources, there are other sources, of lesser significant. Those sources are as follows:

1) The Al-Dibdibba Plain: occupies most of the north and north-western part of Kuwait. It is a continuation of part of the Al-Dibdibba Plain in the southern desert of Iraq. The Al-Dibdibba plain surface is mostly covered by gravel, sand, silt and clay (Khalaf, Gharib and Al-Hashash, 1984).

2) The Northern Coastal Area: This area extends from Ras Ajuza to the northern coastal border with Iraq. The sand dunes in this area occupy a narrow belt along the seaward side (Khalof, Gharib and Al-Hashash, 1984). The width of this belt is ranges from 4 km north of Al-Maghasel to 500 metres near Al-Bahra. The area contains clusters of vegetated dunes. They are mostly composed of about 88% sand (mainly quartzitic), 10.5% of mud and 1.5% of gravel (Al-Bakri, Shublaq, Al-Sheikh, Kittanch and Al-Ghadban, 1982).

3) The Southwestern Area: This area is mostly sandy and flat except that there are some small hills such as the Wara and Burgan Hills (Khalaf, Gharib and Al-Hashash, 1984).

4) Playas: In Kuwait playas are called "Khobra" or "Thamila". These occur throughout the northern, western and central parts of Kuwait, and generally are full of water during the rainy season and dry during the summer time. These playas have a mixed content of sand and silt (Khalaf, Gharib, and Al-Hashash, 1984; Fuch, Gattinger and Holzer, 1968).

5) Wadis: "Wadi" is an Arabic word which means valley. These are dry for most of the year except during the rainy seasons. The main and largest wadi in Kuwait is wadi Al-Batin, which is in the north-western side of the country on the Kuwaiti-Iraqi border. Wadi Al-Batin reaches about 8-11 km in width (Halwagy and Halwagy, 1974). Wadis, such as Al-Batin, contain mainly deposits such as sand sheets which are developed by the coalescing of anchored vegetated sand drifts (Khalof, Gharib and Al-Hashash, 1984).

4.8) Dust Frequencies:

Dust storms and other types of dust phenomena are most frequent in arid and semi-arid regions. Indeed the existence of dust in the air and of dust storm is one of the signs of desertification or aridity (Goudie, 1978, Coles, 1938; Middleton, 1986; Goudie, 1983). Dust storms are more common during the dry season than the wet season and they are more frequent in unvegetated areas or the land in which the vegetation cover has been lost (Kavda, 1980). For instance, in Egypt during World War II, Oliver (1945) compared dust storm frequency from 1939 to 1945 and found that the dust storm occurrence had been increased by up to five times. **(Table 4.11)**

Years	1939-40	1940-41	1941-42	1942-43	1943-44	1944-45
Total No. of Dust Storms	8	40	51	20	46	11

Table 4.11: Number of dust storm days in Egypt from 1939 to 1945. (After: Oliver,p.36, 1945).

This increase of dust storms was due to military activity which destroyed vegetation cover and surface coherence. Wind energy close to the surface increases two or three times over bare surfaces when compared with other types of surface such as vegetation , turf, sod and roots (Kavda, 1980). Another example may be seen in the U.S.S.R., when the "dark storm" is blown from southern Siberia. This phenomenon is mostly composed of airborne black soil material. This material is raised in the air by the strong winds which blow over ploughed steppe virgin land (Nalivkin, 1986). Dust storm frequency over the countries surrounding Kuwait is shown in **table 4.12**.

Country	Location	Average of dust Storms Frequency per year
Iran	Abadan	13
Iraq	Baghdad	21.5
	Basra	14.7
	Diwaniyah	35.9
	Hinaidi	33.2
	Shaibah	37.6
Jordan	Al-Hummar	7.0
	Aqaba	10.7
	H4	16.3
Saudi Arabia	Dharan	11.3
	Riyadh	12.7
	Tabouk	10.8
Syria	Abu Kamal	9.7

Table 4.12: The frequency of dust storms in locations surrounding Kuwait (visibility≤1000m). (After: Goudie, A.S., p.293, 1978).

4.9) Dust Frequency in Kuwait :

Dust phenomena are common in Kuwait throughout the year, but the actual frequency of dust differs from one month to another (Safar, 1985). For example, dust storms are more frequent during the spring and summer months (Safar, 1985). Average dust storm days in June are 4.7 days and in July, 4.3 days. For rising dust, the highest monthly average is in June 10.4 days followed by July 8.4 days **(Table 4.13 & Figure 4.5)**.

Months	% Dusty Days	% Dust Storm	% Rising Dust	% Suspended Dust	% Hazy Days
January	5.9	3.9	5.0	5.1	7.5
February	6.9	4.9	6.5	7.3	7.4
March	8.1	7.7	8.9	8.6	7.4
April	8.5	11.7	8.9	8.5	7.3
May	9.8	15.6	9.6	11.1	7.7
June	10.4	17.8	15.4	8.3	6.3
July	10.2	16.8	12.3	9.9	7.1
August	9.7	8.2	11.9	9.0	7.1
September	9.0	2.2	7.2	10.3	11.3
October	8.3	5.5	5.2	9.6	10.4
November	6.8	1.6	4.1	7.1	10.0
December	6.4	4.1	5.0	5.2	8.7
Total	%100	%100	%100	%100	%100

Table 4.13 : Annual percentage of dust phenomena in Kuwait (1962-1986).

The main points which can be concluded from table 4.4 and figure 4.4. are as follows:

1) Dust phenomena occur throughout the year in Kuwait. This pattern

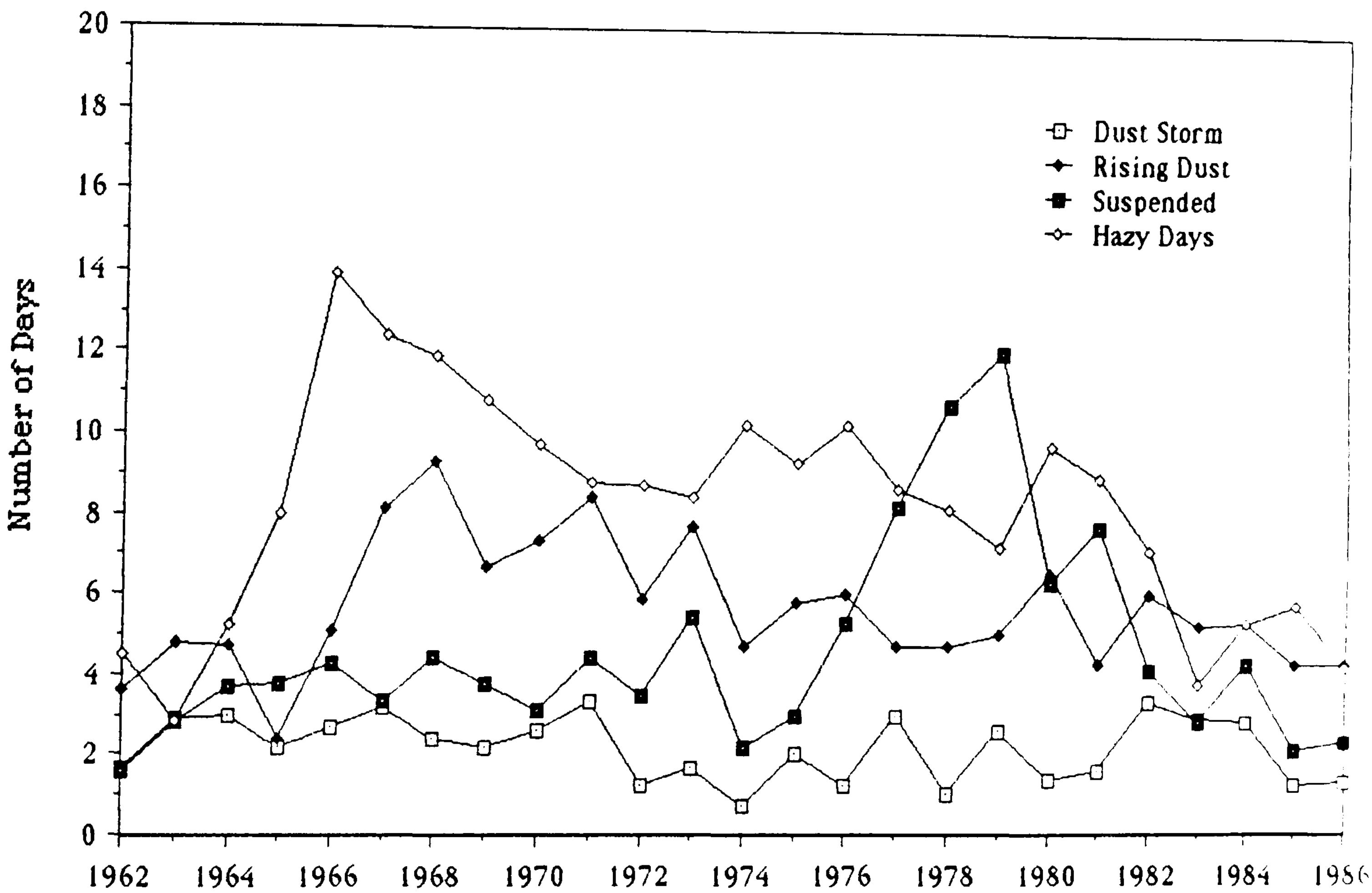


Figure 4-5: Annual number of dust type by days from 1962 to 1986.

is due to several factors including: (Gharib, Al-Hashash, Asem and Foda, 1982 and Safar, 1985):

a) existence of atmospheric turbulence which generates upward currents due to the huge amount of heat which Kuwait receives, especially in summer;

b) prevalance of fresh to strong winds;

c) loose and mobile surface material in and around Kuwait;

d) low or flat physical surface features within the country;

e) limited vegetation cover in the area.

2) The dust phenomenon is however more common during summer time, from May to August, than of other times of the year (Safar, 1984; Al-Kulaib, 1984, Middleton,(A) 1986). This is a result of prevailing fresh or strong north-westerly winds (Shamal) which come from the desert area, especially in June and July, the period of dry summer (Climatological Summaries, 1983; Al-Kulaib, 1984; Safar, 1982). A reversal occurs in north-western China, where dust storms exist during winter half-year, from November to May, when the northern dry and cold winds blow. But, in summer, when moist southern air becomes commoner, the frequency of dust storm formation is reduced (Rahn, Barys and Shaw, 1981).

3) During November (Autumn) both dust storms and rising dust are reduced to a minimum frequency (1.6% and 4.1%). This reduction is due to:

a) The wind speed reduces to an average of 3.6 m/s, the lowestwind speed of any season (Al-Kulaib, 1984, Sharaf, 1980).

b) The moisture in the air increases because of increasing south-easterly winds (Kans) (Al-Kulaib, 1984; Climatological Summaries, 1983). The mean average of relative humidity reaches 52.5%.

4) There are also other noticeable reductions in dust storms and rising dust in September. This month is part of the second half of summer, which is more humid. During this period, the light and very humid south-easterly winds (Kans) start to blow, causing a muggy type of weather (Al-Kulaibn, 1984; Climatological Summaries, 1983). On the other hand, the percentage of calms increase from 7% in June to 12% in August and 14% in September (Al-Kulaib, 1984).

Dust storms are more common during the day than the night. They mostly occur between 0900 to 2100 local time (0600 to 1800 GMT) (Al-Kulaib, 1984) and the most frequent occurrence of dust storms during the day in June and July is at 1300 local time as shown in **Table 4.14** (Safar, 1985):

Local Time	06	07	08	09	10	11	12	13	14	15	16	17	18
No. of Dust Hours	51	102	156	204	224	242	255	257	243	239	235	231	224

Table 4.14: The dust occurrence hours throughout the daytime in June and July (1969-1978) (after: Safar, p.47, (A) 1985).

This confirms their being the result of day time convection associated with solar heating of the land surface.

General characteristics of dust phenomena frequency between 1962 and 1985:

The overall pattern from climatological results can be summarized thus:

1) The highest total of dust storm days are in June, 113 days (15.7%) followed by July 107 days (14.4%).

2) The highest cumulative total of rising dust is in June 252 days (35%),followed by July, 201 days (27.1%).

3) The highest cumulative total of suspended dust occurrence is in May, 150 days (20.2%) and in September, 140 days (19.4%).

4) In the case of haze, the highest monthly cumulative total are September, 270 days (37.5%) and in October, 249 days (33.5%).

5) The highest year for dust storm days was 1982 with 40 days (11.0%), and the lowest frequency was in 1979 with 8 days (2.2%).

6) The highest year for rising dust was 1968 with 112 days (39.5%), and the lowest frequency in 1965 was 29 days (7.9%).

7) The highest year for suspended dust occurrence in 1979 with 144 days (39.5%) and the lowest was 1962 with 19 days (5.2%).

8) The highest number of days of haze in a year was in 1966 with 167 days (45.8%), and the lowest was in 1963 with 34 days (9.3%).

4.10) Dust Deposit in Kuwait:

Dust deposition is largly dependent on the amount of dust in the air and wind speed. Whenever the wind speed is reduced the deposition process will start. The amount of dust deposited in some locations is huge **(Table 4.15)**.

Location	Dust Fall Rate (tonnes/ km^2/year)
Arizona (U.S.A.)	55
Bulgaria	44.5
Caspian Sea	39.5
Kansas (U.S.A.)	56
Kuwait	55
Negev (Israel)	50-200
Northern Nigeria	137-181

Table 4.15: Annual dustfall rate in various locations in the world. (After: Goudie,p.503, 1983).

This huge amount of dust or sand is enough to bury and kill young plants and render roads, railways, runways, pipelines, and cultivated gardens useless (Cook, et al., 1982). The rate of dust deposition differs from season to season, and in general the amount of dustfall is more significant in summer time than winter. For example, in Tempe, Arizona, the winter rate of dust deposition average is 0.1 to 0.15 g/m^2/day, but in summer the average rate is 0.2 to 0.4 g/m^2/day (Péwé et al., 1981). There are examples of cultivated land and villages which have been covered by sand in Al-Hasa, Saudi Arabia. The sand movement decreased the cultivated area of Al-Hasa from that maintained by local people 60 to 100 years ago which was twice as large in size as now (Abolkhair, 1981). Another example is found in Al-Hasa, Juwatha the old capital of Al-Hasa, and occurred 1400 years ago. The Juwatha mosque was covered by sand and not until 1970, was this mosque rediscovered (Abolkhair, 1981; AbdulWahid, 1982).

The same problem exists in Kuwait. Many roads are buried during sand or dust storms, especially non-urban roads. Oil wells are affected by dust and sand storms, as are oil pipelines which run through the desert and some construction buildings in the desert. One of the earliest studies of dust fall in Kuwait was carried out by the Occupational Health and Industrial Pollution Control Section, Ministry of Public Health in Kuwait. Recently the name of this section has been changed to Environment Protection Council (EPC). This study was entitled "Dust Fallout in Kuwait" (1978). The study was carried out between 1969 and 1977. It was based on climatological data from 1962 to 1977. In order to collect the dustfall samples initially seven locations were selected and then later a further ten locations were added. They are: Mid-town of Kuwait City, Shimya, Sulaibikhat, Mutlaa, Farwaniya, Khaldiya, Salmiya, Funtas, Sbhuaiba, Ahmadi, Airport, Messila, Maque, Abu-Halifa, Jaleeb Al-Shugukh, Shaab and Sulaibiya **(Figure 1-2)**.

Throughout the whole period from 1969 to 1977 the highest average weight of dustfall in Kuwait was 85.6 tonnes/km^2 in 1973 and 80.9 tonnes/km^2 in 1971. The highest monthly average weights of dustfall are in June (119.2 tonnes km^2) and July (83.7 tonnes/km^2) **Table 4.16** (Occupational Health and Industrial Pollution Control Section, 1978).

Month	Mean of Dustfall	% of Dustfall
January	30.1	5.0
February	29.6	4.9
March	36.9	6.1
April	63.9	10.2
May	69.6	11.5
June	119.2	19.7
July	83.7	13.9
August	45.9	7.6
September	25.2	4.2
October	37.3	6.2
November	39.0	6.4
December	24.4	4.0
Mean	50.4	100%

Table 4.16: Monthly mean average weight (tonnes/km^2), and percentage of total dustfall in Kuwait from 1969 to 1976 (After: Occupational Health and Industrial Pollution Control Section,p.49, 1978).

During the period 1978 to 1985 dust-fall in Kuwait has increased. The monthly mean average of the period of 1969 to 1975 was 50.4 tonnes/km^2, whilst the monthly mean average of 1978 to 1985 was 99.8 tonnes/km^2. There were also increases in the highest monthly mean values. Thus mean values was 198.6 tonnes/km^2 in August, 170.3 tonnes/km^2 in July and 131.5 tonnes/km^2 in May **(Table 4.17)**.

Month	Monthly Mean	% of Dustfall
January	46.6	3.9
February	65.1	5.5
March	74.0	6.2
April	51.9	4.3
May	131.5	11.0
June	122.5	10.2
July	170.3	14.2
August	198.6	16.6
September	88.8	7.4
October	80.8	6.7
November	65.7	5.5
December	101.8	8.5
Monthly Mean	99.8	100%

Table 4.17: Monthly mean average weight in (tonnes/km^2) and percentage of dustfall weight in Kuwait from 1978 to 1985 (After: Environment Protection Council, 1983; 1984; 1985; 1986).

The weight of dustfall varies from one location to another within Kuwait. This variation remains significant in Kuwait even though the distance between these locations is not great. The highest monthly mean dustfall weights in the period 1969-76 were at Mutlaa (117.7 tonnes/km^2), Jaleeb Al-Shugukh (85.2 tonnes/km^2) and Mid-town of Kuwait City (59.6 tonnes/km^2). The lowest monthly mean of dust-fall weight was at Shaab (15.4 tonnes/km^2) and Sulaibiya (15.8 tonnes/km^2) (Occupational Health and Industrial Pollution Control Section, 1978).

Dust-fall at these locations increased during the period of 1978 to 1985. The highest mean of dust-fall weights were at Mutlaa (235.2 tonnes/km^2), Shuwaikh (197.2 tonnes/km^2) and Shuaiba (112.6

tonnes/km^2). The lowest mean dust-fall weight were at Salmiya (48.6 tonnes/km^2) and Farwaniya (64.3 tonnes/km^2). **(Table 4.18)**.

Location	Mean of Dust-fall (tonnes/km^2/year)	Period
Mutlaa	235.2	1978-85
Sulaibikat	77.2	1978-85
Shuwaikh	197.2	1982-85
Kuwait City	97.9	1978-85
Shamiya	84.9	1978-85
Salmiya	48.6	1978-85
Farwaniya	64.3	1978-85
Fahaheel	93.3	1981-85
Shuaiba	112.6	1978-85
Mean	106.8	
Standard Deviation	52.7	
Coefficient of variation	49.3	

Table 4.18: Geographical distribution of mean annual average of dust-fall weight over various locations in Kuwait from 1978-1985 (tonnes/km^2) (After:Environment Protection Council)

Generally locations which have lowest dust-fall weight are residential areas. For example, Salmiya and Shaab are residential areas and residential buildings offered some protection to these areas. On the other hand, Mutlaa is non-residential area and is located in the desert area of Kuwait, and there are no buildings or trees to protect this area.

A further relevant study is entitled Dust Fallout (Toze) in Kuwait by the Kuwait Institute for Scientific Research (1980). In this study of dust-fall, Kuwait has been divided into three main areas: Northern area, Kuwait city area and Southern area. The Northern area includes: Al-Abdalli, Umm Al-Aish and Mutlaa; Kuwait City area includes: Sulaibikhat, Kuwait Mid-town and Salmiyah; and the Southern area includes: Ahmadi, Fahaheel, Mina Abdulla, Al Wafra and Nuwaisib. The dust-fall observation period was from April 1979 to March 1980, which is of course only a one-year period. During this period the highest monthly amount of dust-fall was in Nuwaisib (530.6 tonnes/km^2) and Mina Abdulla (527.1 tonnes/km^2) which are parts of the southern area. The lowest monthly amount was in Kuwait mid-town (20.8 tonnes/km^2) followed by Salmiyah (54.2 tonnes/km^2) (Khalaf et al., vol. 2, 1980). Generally the southern area has the highest monthly amount of dust-fall (324.6 tonnes/km^2) followed by the northern area (114.8 tonnes/km^2).

The southern area of high dust-fall is related to the Southern Kuwait desert which is composed of sand deposits and Sabkha flat deposits, which are composed of mostly fine particles (Khalof et al., vol. 2, 1980). Also, the area is part of the Arabian desert, therefore dust and sand can move freely toward this area.

The Northern area, which comprises part of the northern Kuwait desert, is covered by residual gravelly deposits. The Al-Abdali, in the north of the country close to the Kuwaiti-Iraqi border, is affected by dust which comes from the Mesopotamian flood plains. These plains are mostly composed of dry muddy sabkhatized sediment (Khalaf et al. vol. 2, 1980) **(Table 4.19)**.

Month	Northern Area	Kuwait City	Southern Area
April	122.3	70.1	245.5
May	86.3	20.9	97.2
June	262.1	42.1	203.9
July	302.3	85.8	1973.3
August	250.5	142.2	791.1
September	118.2	29.8	156.2
October	58.8	28.5	133.9
November	7.6	16.8	7.0
December	63.5	25.9	150.2
January	30.5	15.4	51.8
February	46.9	42.7	100.4
March	29.5	30.7	74.2
Mean	114.8	45.9	324.6

Table 4.19: Monthly average amount of dust fall-out over the three main areas in Kuwait from April 1979 to March 1980 (tonnes/km^2) (After: Khalaf et al. p.125, vol. 2, 1980).

4.11) Dust Generators:

Goudie (1978) claimed that the main factors controlling dust storms are: a source of sand or dust material, strong winds and limited quantity of precipitation which affects the nature of vegetation cover. Middleton (A-1986) said that "dust storm is caused by the action of a strong wind on a loose, dry and sparsely vegetated ground surface". Coles (1938) emphasized that the main areas of dust generation in the world were the dry and sandy soil, poor vegetation cover and sand or dust particles which could be picked up by strong winds.

The character of Kuwait's environment is thus favourable to the generation of dust and sand storms. In fact, most of the factors which have been mentioned, if not all, occur in Kuwait. Therefore, dust storms are common phenomena in Kuwait during any time of year, but especially during the summer. Gharib, Al-Hashash, Asem, Attasi and Foda (1982) described the Kuwait environment as having "low topographic relief, scanty vegetation, light textured top soil and persistent strong and turbulent winds". Thus, the generation dust is affected by several factors, some of them physical and others man-made (Gillette, 1979). As the result, the main dust generating factors in Kuwait are as follows:

1) Location: Kuwait is located between 28° 30` to 30° 05` north of the equator and 46° 33` to 48° 30` east of Greenwich meridian and is therefore, part of the sub-tropical region, affected by the Hadley cell. Furthermore, Kuwait is part of the great desert belt, which extends from the Atlantic coast of north Africa in the West, through the Sahara Desert, eastward to the north western part of China, and the Gobi Desert. Kuwait is surrounded by deserts except in the east. Therefore, Kuwait is part of this huge arid region. In other words, sand and dust sources are available in this area.

2) Wind System: Winds play the main role in the dust storm generating process. This is because if dust or sand particles are to be moved, they need a fresh to strong wind speeds for movement. In Kuwait, the mean wind speed has a maximum in June of 5.8 m/s, and a minimum in November of 3.3 m/s **(Table 4.20)**.

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Mean Wind Speed (m/s)	3.6	4.1	4.6	4.7	4.7	5.8	5.4	4.7	3.8	3.5	3.3	3.6
Max. Wind peed (m/s)	19	19	20.6	23.1	29.3	20	18.5	19	17.5	21.6	16.9	19

Table 4.20: Mean of surface wind speed (m/s) at Kuwait International Airport (1958-1980). (After: Safar,p.64, 1985).

The annual mean wind speed is 4.6 m/s. The period of fewest calms is in June (6.62%) followed by July (8.3%) for the period of 1957 to 1973 (Safar, 1985). The wind typically reaches its daily maximum speed during the afternoon and its minimum in the night and early morning (Safar, 1985). The prevailing wind direction in Kuwait is northwesterly. During the period of 1957 to 1973 based on hourly mean values at Kuwait International Airport show that 43% of annual winds are north-westerly, 18% south-easterly, 13% northeasterly, 12% south-westerly and 12% calm.

Therefore, it is highly probable that most of the dust comes with north-westerly winds from the southern part of Iraq and the Mesopotamian flood plains (Khalaf et al., vol. 2, 1980; Safar, 1985).

3) Turbulent Surface Layer: Turbulence is also one of the main factors in dust generation (Coles, 1938). Commonly a dust storm begins after the sunrise and becomes stronger during early afternoon (Coles, 1938; Banoub, 1970; Loewe, 1943). Turbulence ceases or weakens in the late afternoon and during the night time when the night inversion occurs. Thus dust storms tend to reduce during night time. This surface turbulence is associated with intense convection which provides both upward and downward currents (Coles, 1938; Baroub, 1970; Loewe, 1943).

4) Soil (Sand) State: Generally, the surface of arid and semi-arid regions is characterized by sandy, dusty, loose materials. Such loose materials are easily moved or carried away by the wind. Kuwait soils have formed under arid conditions, and are therefore sandy and saline in nature (Al-Fell, in Beaument and McLachlan, 1985; Oedekoven, in Kaule, 1970; Halwagy and Halwagy, 1974). These conditions cause the soil coherence to be weak. Therefore, soil are liable to erosion giving a source of sand and dust, which may be carried into the air as a dust storm.

5) Lack of Rainfall: One of the most obvious characteristics of arid and semi-arid zones is lack of rainfall. Kuwait, as a part of the arid region, has very low annual rainfall with an average annual of about 108.8 mm. The standard deviation of average annual rainfall for the period of 1962 to 1986 is 50.4 mm, which means the amount of rainfall is quite variable from one year to another. The maximum annual rainfall recorded in that period was 242.4 mm in 1976 and the minimum was 31.3 mm in 1964. Monthly amounts are not stable with noticeable fluctuations from one month to another, as well as from one year to another as is shown by the range of coefficient of variation **(Table 4.21)**.

Rainy Months	Jan	Feb	Mar	Apr.	May	Jun-Sep	Oct	Nov	Dec
Mean (mm)	27	15.5	11.1	15.4	4.6	0	3.6	13.4	17.4
Coefficient of Variation %	66.1	132.2	92.8	133.1	130.4	0	311.1	164.9	94.8

Table 4.21: The mean rainfall of rainy months (mm) and coefficient of variation (%) for period of 1962 to 1986.

Generally the types and number of dusty days are closely related to the quantity of precipitation; an increase in the latter (and thus of soil moisture and vegetation cover) causes a reduction in the former (Goudie, 1978).

But in the case of Kuwait, the amount of rainfall is too small to support significant vegetation cover and soil moisture. The correlation between the number of rainy days and the annual rainfall quantity with annual number of dust type days is thus low **(Table 4.22)**.

The low rainfall, both in quantity (mm) and duration, results in poor vegetation cover and soil moisture. As a consequence soil coherence will be weak, thus the soil becomes dry, loose, and sandy. In these circumstances strong wind can easily raise up sand and dust in the air, producing sand and dust storms.

(Y) No. of Days	(X) Quantity of Rainfall (mm) r	(X) No. of Rainy Days r
Dusty Days and Haze	0.2	0.3
Dust Storms	-0.07	-0.3
Rising Dust	0.1	0.3
Suspended Dust	0.08	0.04
Hazy Days	0.35	0.3

Table 4.22: Correlation coefficient of the annual total of quantity of rainfall (mm) and annual number of rainy days, with annual number of dust type days from 1962 to 1986.

There are no significant correlations between the annual number of dusty days and both annual rainy days and quantity of rainfall (mm) except in the case of hazy days, which is significant at the 0.05 level. Also, for most of the dust types the correlation is positive except in the case of dust storm which is negative correlation. That confirms that precipitation plays a minor role in dust storm generation or reduction.

Two factors affecting the relationship between the dust and rain are significant. They are:

1) The amount of rainfall is too small to stabilize the sand and dust or to support a significant vegetation cover.

2) Both dust and rain can be associated with cold fronts which pass through the country during winter and spring-time. Also, both dust and rain, are associated with the thunderstorms which are more common in Kuwait during March and April and are locally named "Sarrayat" **(Table 4.23)**.

Months	No. of Thunderstorms Days Without Dust	No. of Thunderstorms Days with Dust
January	16	21
February	10	23
March	20	40
April	24	56
May	10	64
June	-	2
July	-	1
August	-	-
September	-	-
October	7	20
November	22	18
December	25	23

Table 4.23: Total number of thunder storm days with and without dusty days including haze by month, from 1962 to 1986.

On the other hand, the relationship between the monthly average of types of dust occurrence, including haze, and the monthly average of rainfall is generally more significant than the relationship based on the annual values **(Table 4.24)**.

Monthly Mean No. of Days	(Versus)	Mean of Monthly Rainfall(mm) r
Dusty Days and Haze		-0.9
Dust Storm		-0.5
Rising Dust		-0.6
Suspended Dust		-0.8
Haze		-0.2

Table 4.24: Correlation coefficient between the monthly mean of days, number of dust types with monthly mean of rainfall (mm) in the same month (1962-1986).

The negative correlation indicates an inverse relationship between the monthly average of rainfall (mm) and monthly average number of days, of dust types. The correlation is significant in all cases, except in the case of haze. The significance in the case of average number of dusty days including haze is at the 0.005 level, rising dust at the 0.05 level and suspended dust at the 0.005 level. In the case of dust storms, the value calculated is not significant at the 0.05 level, but is close to the 0.05 level. These significant correlations are particularly affected by the four dry months from June to September. This dry period can include May and October. During this dry period when the quantity of rainfall is insignificant, the existence of dust is more frequent.

For example in Sudan, at El Fasher (13°32'N 25°21'E), east of Sahel, during the low rainfall period of 1972 and 1973, dust storm frequency increased; in 1975 and 1976 the dust storms decreased because of a high rainfall season in 1974, and again in 1978 the dust storms increased again to nine storms per year as a result of a decline in the rainfall (Middleton, 1985). Another example is at Nouakchott, Mauritania, where dust storms are more common, from January to May before the rainy season. In west Africa, in Cayenne, French Guiana where rainfall in years 1970 and 1971 dropped to about 32% (48.1 mm) and 12% (17.9 mm) below the average of the period 1949 to 1967 the number of dust storm days increased from 12 days in 1970 to 65 days in 1974. But in 1975 when the amount of rainfall increased to about 190.6 mm, so the dust storm days declined to 25 days in 1976 and to 27 in 1977. When again rainfall dropped to 2.7 mm in 1977, dust storm activity rose to 55 days in 1978 and 61 days in 1979 (Middleton, 1985). Another example, from Iraq, can be found in two zones west of Baghdad, and in the west of Basrah where dust storms are more frequent (Al-Najim, 1975). Both zones are part of the Western Desert of Iraq. Generally dust storms in Iraq are controlled by rainfall, so that during the rainy months the ground becomes moist or muddy and dust storm frequency declines. At Mosul, in the north of Iraq, for example, the average rainfall is over 40 mm in each month from November to April, so dust storms are uncommon during these months (Coles, 1938).

In the case of relative humidity in Kuwait, there are negative relationships between relative humidity and dust phenomena occurrence, except in the case of haze. The correlation coefficient between the monthly mean values of relative humidity and monthly mean of dusty days including haze existing are shown in **table 4.25**.

Mean No. of DaysMonthly	(Versus)	Mean of Relative Humidity (%) r
Dusty Days and Haze		-0.98
Dust Storm Days		-0.7
Rising Dust		-0.8
Suspended Dust		-0.8
Hazy Days		+0.04

Table 4.25: The correlation coefficient between the monthly mean of the dust types days existence and the mean of relative humidity values (%) (1962-1986) in Kuwait.

On the other hand, the correlation coefficient between the annual number of dust type occurrence and the annual mean values of relative humidity is insignificant but negative, with the exception of haze, which has a significant correlation at the 0.05 level and positive **(Table 4.26)**.

Annual No. of days	(Versus)	Annual Average of Relative Humidity (%) r
Dusty Storm		-0.3
Rising Dust		-0.08
Suspended Dust		-0.2
Hazy Days		+0.4

Table 4.26: The correlation coefficient between the annual number of days of dust types occurrence and the annual mean values of relative humidity (1962-1986) in Kuwait.

Generally, from table 4.25 and 4.26 it can be concluded that there are negative correlations between the occurrence of dust types and relative humidity except in the case of haze. The increase of moisture in the air keeps the soil moist. Therefore, the occurrence of dust types is reduced.

6) Lack of Vegetation Cover: Limited vegetation cover is one of the characters of arid and semi-arid zones, as a result of lack of rainfall and poor sandy soil. The natural vegetation of Kuwait is largely conditional by the characteristics of rainfall (Kaul and Junk, 1970; Halwagy and Halwagy, 1974). Vegetation is affected by both total rain quantity and rain duration. For instance, when the quantities of rainfall in 1967-68, 1968-69 and 1971 rose to 162 mm, 159 mm and 223 mm. as recorded at Shuwaikh station, the Kuwait desert was covered with a green mantle. But in the years 1966-67 and 1969-70, the rainfall was 57 mm and 54 mm. respectively the vegetation cover was completely absent (Halwagy and Halwagy, 1970). The main types of vegetation cover are desert grasses, herbs, bushes and some shrubs. Some of these plants are salt resistant (Kaul and Junk, 1970).

7) Human Impact on the Environment in Kuwait: Humans play an important role in the environment which influence dust phenomena. Generally, this role can be divided into two categories:

a) positive role, which, by protecting the environment, reduces the degree of hazards;

b) negative roles which by damaging or destroying the environment by human abuse, results in increased dust activity.

The negative side of the human activities will be considered first, and then the positive side will be discussed; dealing with environment protection to reduce the effect of dust storms or other dust types.

One of the main negative human activity resulting in the encouragement of dust phenonmena is breaking soil coherence or destroying the natural vegetation cover. These activities can result from over-grazing, using plants as a fuel or the destruction of plants by vehicles (Wilshire, 1980). These types of activity disturb the limited vegetation cover of arid or semi-arid environments. In the case of Kuwait, there are many such human activities which encourage dust to move into the air. Further examples include gravel and stone quarrying where there is digging and crushing of the gravel and stone into small pieces for building and construction purposes (Gharib, 1983) and results in local dust formation. Also, lorries which carry these materials destroy both soil coherence and the vegetation cover (Gharib, 1983). In a study by Kuwait Institute for Scientific Research entitled "Contribution of Urban Traffic to Ground Dust Rise in Kuwait City" by Foda, Hashash and Gharib (1983) these problems were studied. The method used to calculate the amount of dust generated is expressed in the following formula.

$$F = 1/2\, n\, p\, V^2 B^2$$

where, F : total dust raising lifting force

n: overall proportionality coefficient which is given by the fraction of surface sediment less than 20 μm (0.02 mm).

p: air density

V: vehicle speed

B: vehicle width

This formula was based on the effect of turbulence caused by motor vehicles moving over loose ground. This turbulence causes fine particles to be raised from the ground, and is due to pressure drop behind the vehicle wake.

People disturb the environment by their personal activities. During the spring many people go to the desert for camping trips,which may last for one month or more. It is a type of traditional cultural and recreational activity among Kuwaiti people. There are no specific places for camping. The camping season starts in February after the rainy months and lasts until the end of April. In December and January, the main rainy, months plants start to germinate and grow and the desert becomes green. In the camping period which follows when people run over these plants with their cars and motor cycles, or remove them from the camping area by picking them or use them for fuel for fires much vegetation is destroyed **(Plates 4-6 & 4-7)**. Beside this, some local people use these plants to feed their livestock. Grazing by goats and sheep plays an important role in disturbing soil coherence and vegetation cover, though the numbers of these animals, and therefore their effects are now tending to decrease **(Table 4.27)**.

	1980-81	1981-82	1982/83	1983-84	1984-85
Sheep	253153	230832	239817	2491320	1819207
Goats	11930	15749	12415	18117	18259
Total	265083	246581	252232	2509437	1837466

Table 4.27: Total number of sheep and goats in Kuwait (Annual Statistical Abstract, 1986).

Although the area of pasture in Kuwait is about 17,179,100 donum (donum=1000m^2) (Annual Statistical Abstract, 1986) this area has limited vegetation cover, which is strongly dependent on winter rainfall. Even limited use by sheep and goats leads to destruction of the vegetation cover and if overgrazing or damage to soil coherence occurs the damage many be severe. Moving animals over the ground and destroying vegetation cover by trampling, are further contributory factors to dust generation.

Plate 4-6: Natural vegetation which has destroyed as a result of off road vehicles, as shown there are two paths over the vegetation cover. This increases the area of desert, by encouraging erosion of bare ground and reduction of the sand's coherence. Therefore, in these location dust generations is more likely.

Plate 4-7: A plant, Cornulaca leuantha, in the desert which has been crushed by a vehicle. Half of this plant was undamaged and still green but the other, as shown to have been crushed by the tyre marks, is dead. This type of shrub depends on rain water and soil moisture. It is used to feed sheep and camels.

PART TWO

CHAPTER FIVE: THE IMPACTS OF DUST ON VEHICLE AND ROAD TRAFFIC

In the main transportation whether road, air or sea depends largely on good horizontal visibility to avoid hazards and accidents. There are many weather phenomena that reduce horizontal visibility including fog, heavy rain, heavy snow, sand storms, and dust storms. In arid and semi-arid regions sand and dust storms play the main role of reducing visibility. For instance, there is a sign on Interstate Route 8 between Phoenix and Tucson (Arizona, U.S.A.) stating "Blowing Dust, Reduce Speed" (Idso, 1976, p. 108) **(Figure 5-1)**.

Many road accidents occurring on highways between Phoenix and Tucson are related to blown dust in that area (Brazel and Hsu, 1981). For example, there were 38 dust related accidents recorded in Arizona between 1968 to 1975. There were 23 accidents, of the 38 dust related accidents, involving a total of 88 vehicles (Hyets and Marcus, 1981). Also, many multiple vehicle accidents occur on Interstate 8 and 10 in Arizona because of dust storms (Benjamin and Hyers, 1981).

As a result of high accident rates, the Transportation Department of Arizona State designated a highway Dust Storm Alert System (DSAS). This system has been described by Burritt and Hyers (p. 288, 1981) as follows:

"... the warning system consisted of 40 electronically controlled, changeable-message signs along a combined

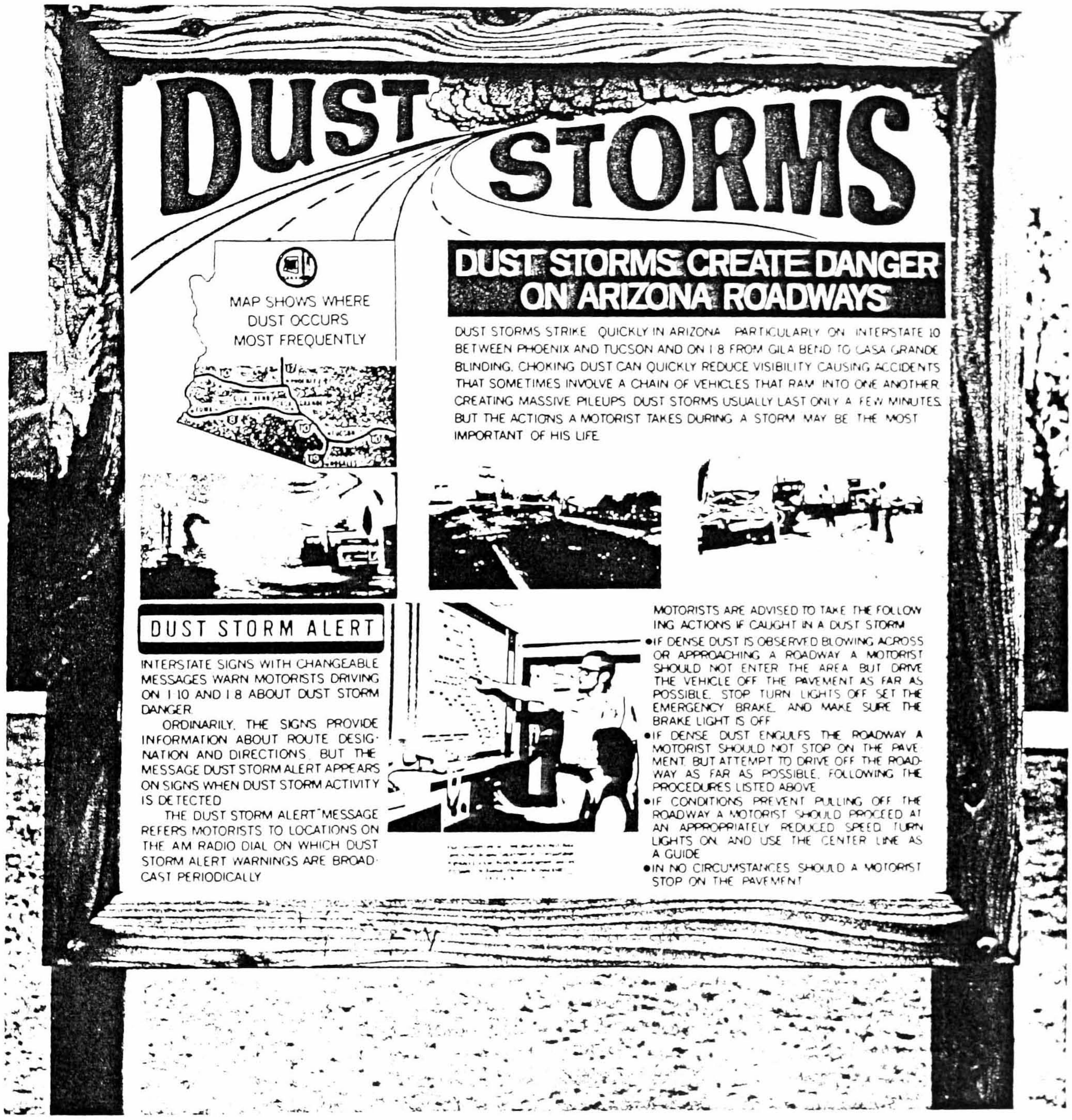


Figure 5-1: Typical sign at rest stop along the highways in Arizona. (after: Péwé, et al., p.187, 1980)

length of 132 km of Interstate 8 and 10 (I-8 and I-10) in central Arizona; their purpose was to provide motorists with timely warnings of dust storm conditions at specific locations in the warning system area. The signs are spaced approximately 8 km apart in both directions"

"...each sign installation was designed as a self-contained unit, each has its own direct-current drive motor, control panel and battery pack, thermo-electric generator, fuel tank and a radio-controlled, 450 megacycle transmitter and receiver with coding equipment".

"Operation of the system involves personnel and facilities of both the National Weather Service and Department of Public Safety. Utilizing weather radar, the weather service can detect and report through its teletype network major dust storms in advance of their arrival on I-8 and I-10. Highway patrolmen in the field also provide advance information to the sign systems "control console" at the Department of Public Safety headquarters in Phoenix"

"A triangular drum in each sign can be rotated to display up to three different messages. Mode (1) is a green guide sign with a standard route shield and direction displayed. Mode (2), the early warning mode, displayed black characters on a yellow background with the worlds "gusty winds-use caution". Mode (3), the severe-warning mode, was a black "blowing dust-reduce speed" on a yellow back-ground".

This system which has been named the Dust Warning System was introduced in 1975.

In order to evaluate the effectiveness of Dust Storm Alert System, a survey was carried out. This survey used a sample based on the license plates of vehicles seen in the system area during, or before the blowing dust storm. There were 1776 questionnaires sent out by mail, but only 715 responded (40%). The main result of the questionnaires were as follows (Burritt and Hyers, pp. 289, 1981):

1) 60% of respondents said that warning messages appropriate for the weather type were encountered.

2) Precautionary action were taken by the drivers due to the weather. 66% of the respondents made their judgement based only on weather conditions, 21% based on the signs and 13% on both weather condition and signs.

3) In response to questions on the helpfulness of the signs, 46% of the drivers said that the signs helped "very much", 45% said helped "some" while 9% said the signs "did not help at all".

4) When questioned about their reaction toward the sign messages, 79% of respondents reduced speed and remained on the road, 8% left the roadway, 4% left the freeway at an exit ramp whilst only 9% of respondents continued driving at the same speed.

It should be borne in mind that there are other factors which play major roles in road accidents such as exceeding the speed limit, driving an unsafe vehicle, careless driving, etc. Furthermore there are other weather conditions which reduce visibility such as fog, heavy rain, or smoke besides the dust storms.

In Kuwait the main two weather conditions which affect the visibility reduction are fog and dust storms **(Plate 5-1)**. Generally fog and

Plate 5-1: Severe summer dust storm where the sky been completely obscured by dust cloud and become red. The visibility is less than five hundred metres and vehicles are using their lights to avoid road accidents and to warn other drivers. The picture was taken at about one p.m. in the afternoon on the As Safar Motorway (south to north of country). The distance between each lighting post is about 50-60 metres. There is bare ground in the desert on the right side of the photograph and the dust storm is blowing from a north westerly direction.

dust storm play a major role in winter time and the dust storm in the summer time. The correlation between the dust types and visibility made over a period of 23 years from 1962-1985 are shown **tables 5.1 & 5-2.**

	Visibility Range (in km)					
Dust Types	V≤0.5	0.51≤1	1.1≤2	2.1≤4	V≤4	V>4
Dust+Haze	+0.377	+0.375	+0.479	+0.633	+0.686	-0.655
Dust-Haze	+0.576	+0.571	+0.731	+0.756	+0.898	-0.884
Dust Storm	+0.772	+0.378	+0.462	-0.2	+0.2	-0.19
Rising Dust	+0.21	+0.138	+0.321	+0.1	+0.207	-0.17
Suspended Dust	+0.33	+0.493	+0.547	+0.921	+0.901	-0.912
Haze	+0.032	-0	-0	+0.235	+0.164	-0.122

Table 5.1: Correlation coefficient between the annual number of days of visibility range and annual number of days of dust types in Kuwait for the period of 1962 to 1985 (d.f. = 23, significant level of 0.05=0.352)

	Visibility Range (in km)					
Dust Types	V≤0.5	0.51≤1	1.1≤2	2.1≤4	V≤4	V>4
Dust+Haze	+0.253	+0.603	+0.39	+0.846	+0.681	-0.55
Dust Storm	+0.744	+0.903	+0.575	+0.715	+0.927	-0.842
Rising Dust	+0.391	+0.862	+0.736	+0.688	+0.847	-0.784
Suspended Dust	-0.003	+0.204	-0.126	+0.727	+0.291	-0.168
Haze	-0.719	-0.873	-0.659	-0.157	-0.739	+0.802

Table 5-2: Correlation coefficient between the monthly total of days of visibility range and monthly total of days of dust type in Kuwait for period of 1962-1985. (d.f.=11, significant level of 0.05=0.521).

Analysis of tables 5.1 and 5.2:

1) The monthly correlation coefficient values between number of days of visibility range and dust types is more significant than the annual values because in the case of monthly data, fog and rain effects are absent during the dry seasons. Therefore the dust effect on visibility can be seen clearly during the dry months. On the contrary, the annual values are affected by foggy and rainy days throughout the period **(Figures 5.2, & 5.3)**. In addition to this analysis of annual and monthly total values, the correlation for the period using individual monthly values was also used. It shows significant correlation between monthly number of days of visibility ranges and monthly number of dust types; especially in case of dust storm for visibility range less than 0.5 km (+0.628) and for visibility range between 0.51 to 1 km (+0.516). Also, there is a significant and positive correlation between dust types and visibility range less than 4 kilometres, except in case of haze. The correlation are with dusty days (+0.569), dust storm (+0.517), rising dust (+0.326), suspended dust (+0.653), and haze (-0.202) for degrees of freedom 287.

2) All dust types have a negative relationship with visibility ranges of more than 4 km **(Figures 5.4, & 5.5)**. This is recognized as the range of good visibility in which dust phenomena are uncommon. In this range however there is the probability of the occurrence of haze.

3) There are some dust types which have a strong negative correlation with visibility range of more than 4 km. These types include the dusty day class but exclude haze and suspended dust conditions. The correlation in the case of dusty days with haze is -0.655 but without haze the correlation became even stronger -0.884. This is due to the existence of haze. It occurs more commonly in the second half of the year, and therefore affects the correlation with dusty days with haze. Also, the

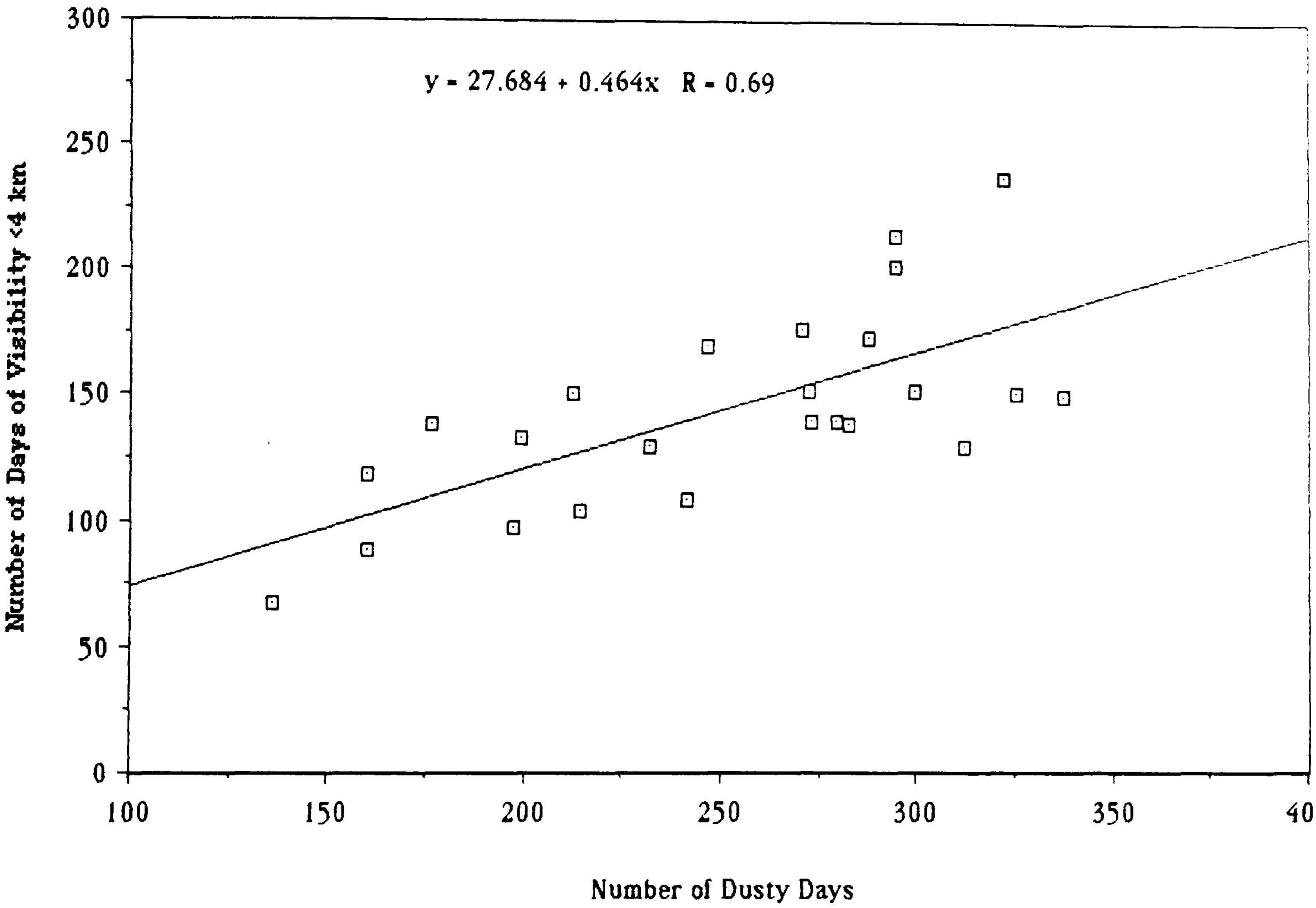


Figure 5-2: Correlation coefficient between the annual number of days of visibility less than 4 km and the annual number of dusty days (1962-1985).

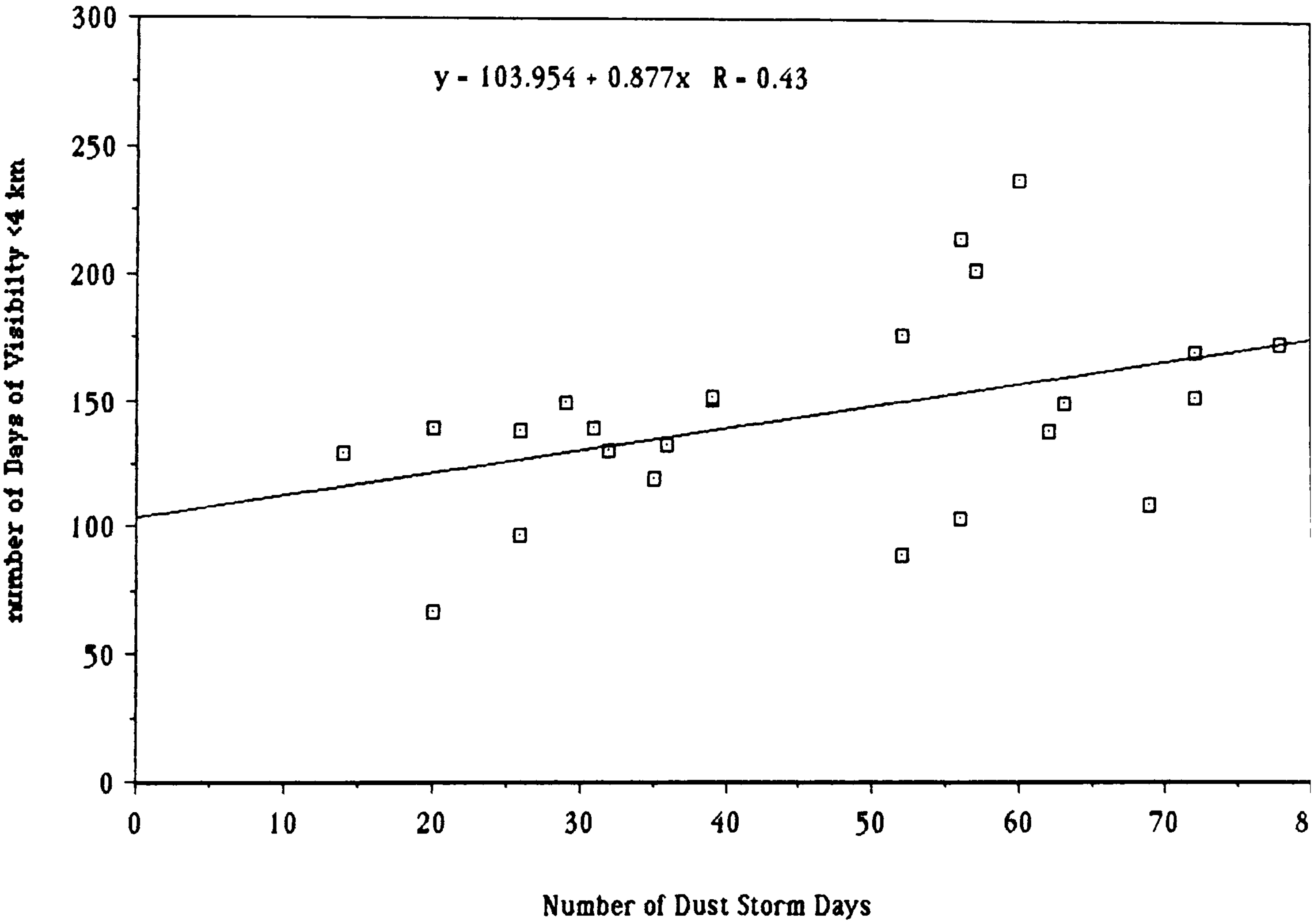


Figure 5-3: Correlation coefficient between the annual mumber of days of visibility less than 4 km and the annual number of dust storm days (1962-1985).

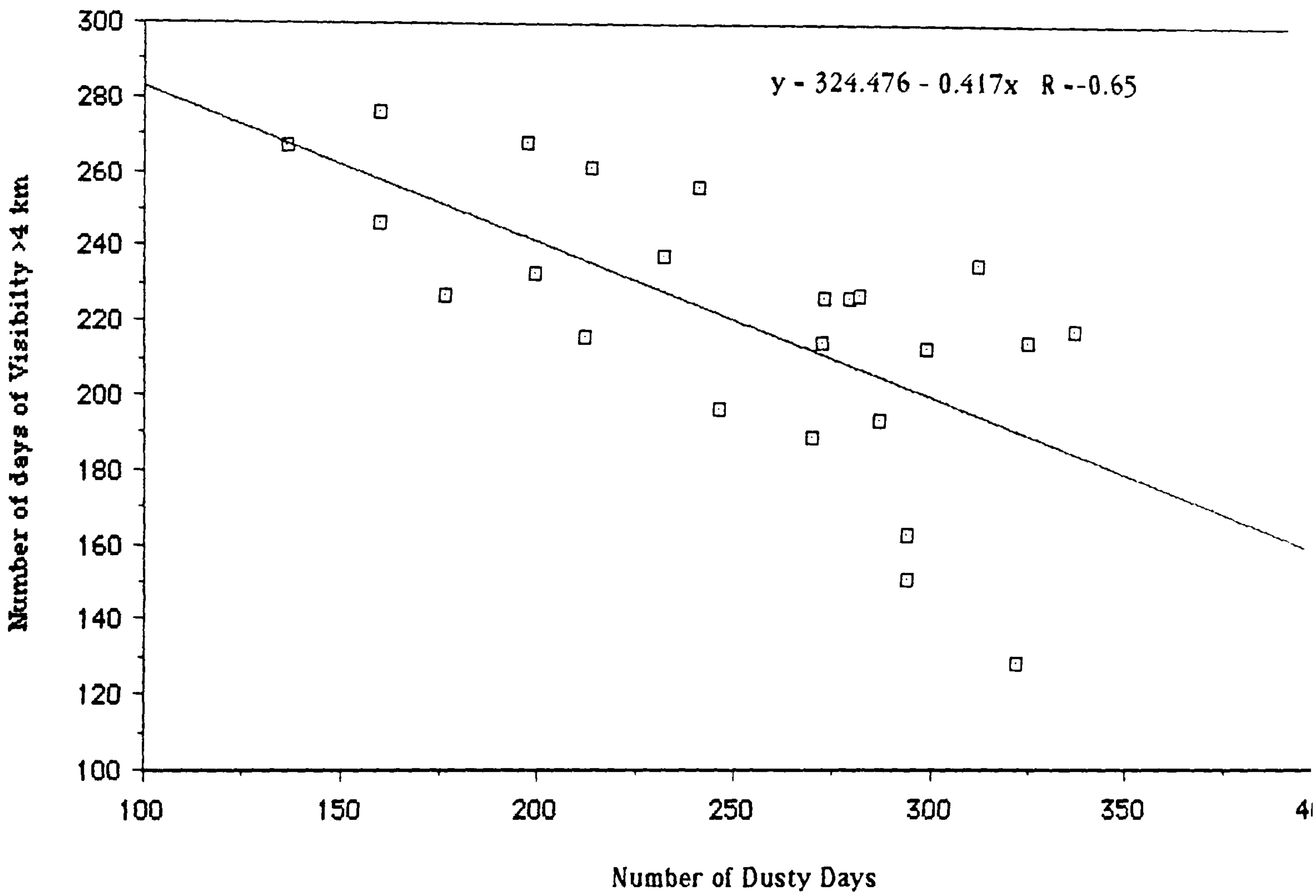


Figure 5-4: Correlation coefficient between the annual number of days of visibility more than 4 km and the annual number of dusty days (1962-1985).

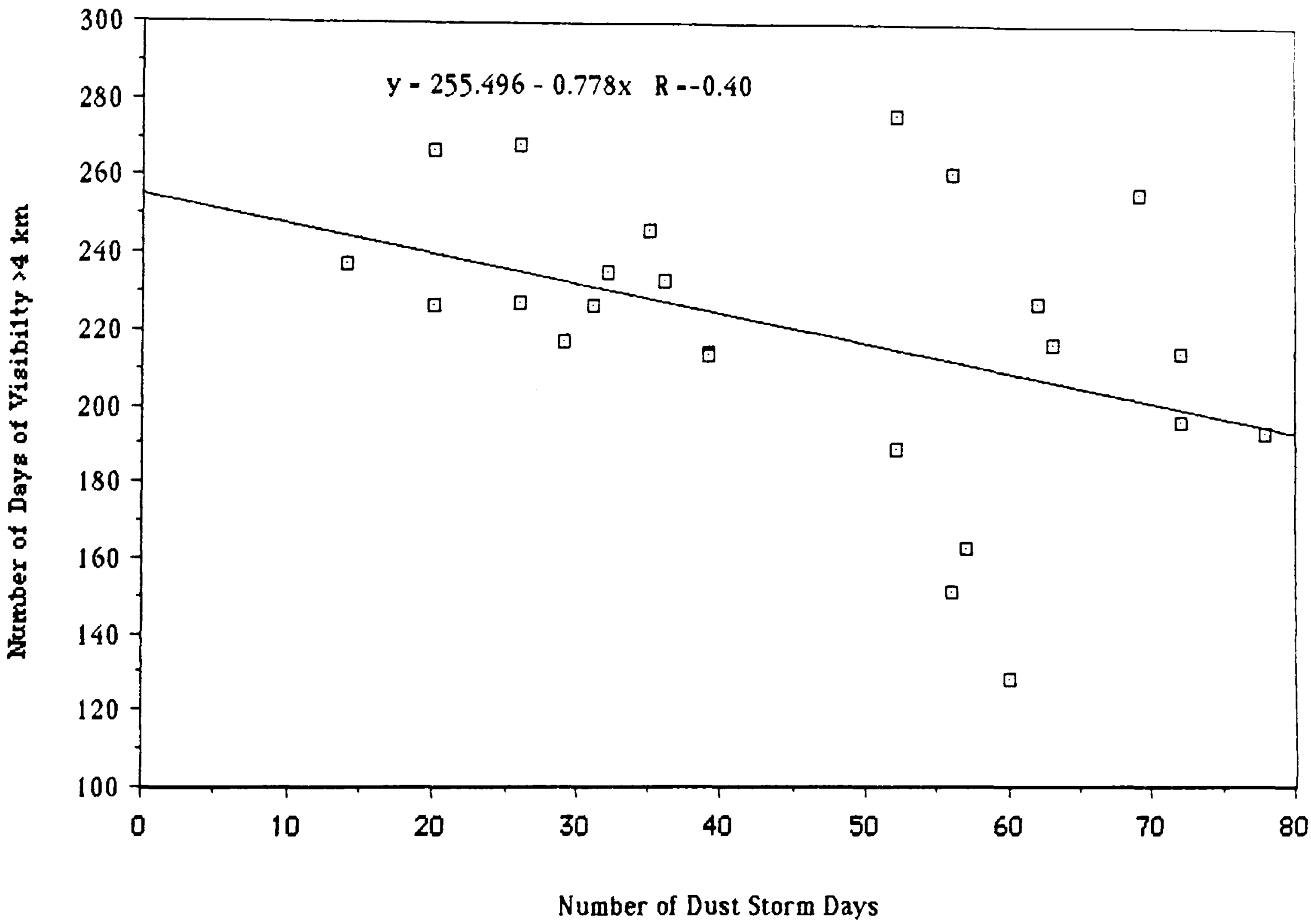


Figure 5-5: Correlation coefficient between the annual number of visibility of more than 4 km and the annual number of dust storm days (1962-1985).

dust content of haze is less than that of other types. There is a strong correlation between the annual number of days of visibility ranges of less than or equal to 4 km and annual number of dusty day without haze. That is because most of the dusty types are occur more commonly with visibilities in the range of less than or equal to 4 km. In the case of suspended dust, it more commonly occurs in the range of visibility less than 4 km and especially in the intermediate range of 2.1 km to less than or equal to 4 km (+0.921). It is significant in this range because particles are smaller than the other types like dust or sand storms. Unlike dust storm and rising dust, suspended dust rises mostly as a result of local wind. Because of the small particle size, it does not need a strong wind to rise.

4) There is a strong correlation between dust storms and visibility range of less than or equal to 500 metres. This is because it is more common for dust storms to be reported when visibility falls below 500 meters. In some cases the visibility may reach zero especially if a dust cloud is present. Clearly it is very hazardous to drive at all during such conditions. If this condition occurs whilst driving the advice is to pull to the side of the road and to remain stopped until visibility improves.

5) There is no significant relationship between rising dust with visibility ranges, except for the range of 1.1 km and less than or equal to 2 km (+0.321). Rising dust does not have a significant role in reducing visibility to less than 1000 metres. Thus it does not have a major part in dust-related road accidents in Kuwait.

6) It can be concluded generally that there is a strong positive relationship between dust types without haze and visibility ranges. This is because the existence of dust has a direct effect on visibility reduction. This reduction in turn produces adverse responses from drivers and

pilots. For example personal contacts have reported that on many occasions during summer flights have been delayed of because poor visibility due to dust clouds. Recently the Al-Watan newspaper reported on Thursday 15/6/1989 (vol. 5146, pp.5) that on Wednesday two aircraft, one from Dubai and the other from Bombay were transferred to Bahrain airport, due to poor visibility in Kuwait airport as a result of severe dust storms.

Because of unavailability of data on dust-related road accidents in Kuwait, the correlation coefficient method has been adopted. This method has been used to show the relationship between the total number of road accidents in Kuwait by each Governorate from 1970 to 1985 and the number of days of the various visibility ranges and the number of dust type days. There is an exception in the case of Jahra Governorate which was separated from Capital Governorates in 1980. In the case of the Jahra Governorate road accidents data is available, but from 1980 only. The correlation coefficients are shown in **table 5.3**.

	Capital Gov.	Hawalli Gov.	Ahmadi Gov.	Jahra Gov.	Kuwait
Dust + Haze	+0.451	+ 0.0	- 0.262	+ 0.241	-0.060
Dust - Haze	+ 0.661	+ 0.304	+ 0.084	- 0.023	+ 0.255
Dust Storm	+ 0.099	+ 0.142	+ 0.182	- 0.818	+ 0.155
Rising Dust	- 0.460	- 0.538	- 0.595	+ 0.120	- 0.552
Suspended Dust	+ 0.874	+ 0.509	+ 0.284	+ 0.275	+ 0.458
Haze	- 0.206	- 0.521	- 0.682	+ 0.478	- 0.559

Table 5.3 : Correlation coefficients between annual road accidents in Kuwait and the Governrates and the annual number of dust type days (1970-1985) (d.f.=14, Jahra d.f. = 4).

The level of significance used is 0.1. Below this level with 14 degree of freedom, the value of correlation coefficient which is significant is 0.458. This level of significance has been adopted because there other factors influence road accidents in Kuwait, including fog and exceeding the speed limit. Generally, the correlation is not strong between road accidents in both the whole of Kuwait and its Governorates and dust types. There is a weak correlation between the road accidents and dusty days including haze **(Figure 5.6)**. The strongest correlation is between road accidents in Capital Governorates and dusty days excluding haze (+0.661). There is no significant relationship between road accidents and dust storm days **(Figure 5.7)**. But in the case of the Jahra Governorates the correlation is negative and noticeable (-0.818).

Road accidents have a negative relationship with rising dust **(Figure 5.8)** in Capital, Hawalli and Ahmadi Governorates but not in Jahra which has a positive correlation. However, in the case of suspended dust the relationship is positive **(Figures 5.9, & 5.10)**. The strongest correlation is in Capital (+0.874) and Hawalli Governorates (+0.509). These two Governorates are more affected by suspended dust carried by the wind from the northern desert of Kuwait. Further south Kuwait Bay reduces the effect of sand dust storms which blow from the north west. Haze does not have a strong effect on road accidents. That is because particles forming haze are so small that they rise up to high altitude. Also, the relationships between road accidents in Kuwait and its Governorates and the annual number of rainy days, the annual amount of rainfall and annual number of foggy days is weak. **(Table 5.4)**.

	Capital	Accidents by Governorates Hawalli	Ahmadi	Jahra	Kuwait.
No. of Rainy days	- 0.102	- 0.137	- 0.111	- 0.674	- 0.147
Quantity of Rainfall(mm)	+ 0.015	- 0.248	- 0.279	+ 0.195	- 0.258
No. of Foggy Days	+ 0.511	+ 0.190	+ 0.061	+ 0.366	+ 0.160

Table 5.4: Correlation coefficients between the annual number of road accidents in Kuwait and its governorates and the annual number of rainy days, annual quantity of rainfall (mm) and annual number of foggy days (1979- 1985) (d.f. = 14, Jahra Gov. d.f. = 4).

Generally, the correlation is weak, except in case of road accidents in capital Governorates and fog (+0.511).

Weather phenomena such as dust and fog affect horizontal visibility range; thus low visibility range has a strong influence on the drivers and causes accidents **(Table 5.5)**.

	Capital	Hawalli	Accidents Ahmadi	Jahra	Kuwait
V.≤0.5 km	+ 0.441	+ 0.191	+ 0.184	- 0.837	+ 0.188
0.51≤1 km	+ 0.545	+ 0.818	+ 0.575	- 0.195	+ 0.696
V.≤1 km	+ 0.577	+ 0.499	+ 0.421	-0.676	+ 0.486
1.1≤2 km	+ 0.604	+ 0.644	+ 0.524	-0.663	+ 0.622
V.≤4 km	+ 0.8711	+ 0.548	+ 0.350	-0.109	+ 0.511
V.>4 km	- 0.870	- 0.548	- 0.355	+ 0.119	-0. 510

Table 5.5: Correlation coefficient between road accidents in Kuwait and its Governorates and the number of days of particular visibility range 1979-1985 (d.f. = 14, Jahra d.f. = 4).

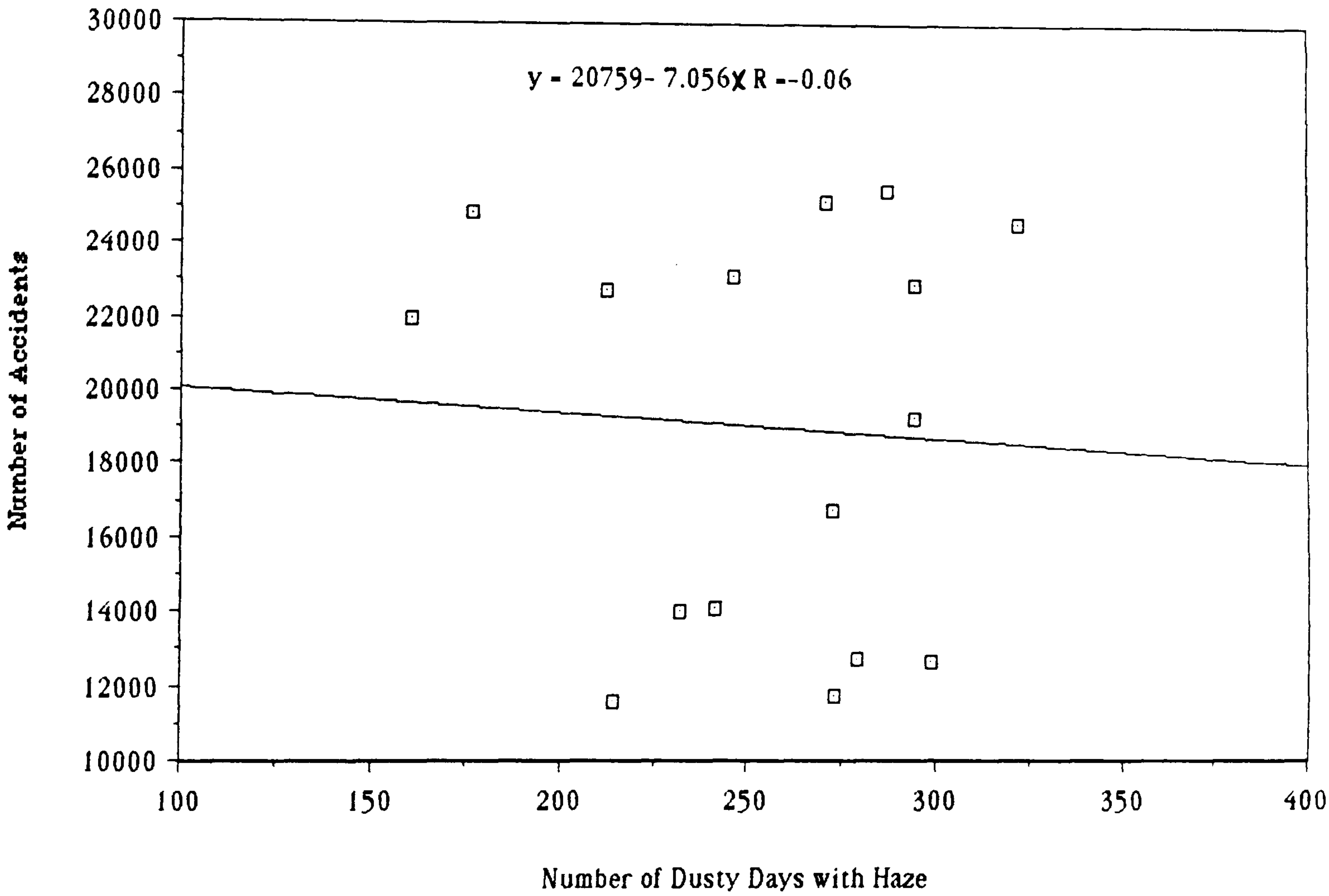


Figure 5-6: Correlation coefficient between the annual number of road accidents and the annual number of dusty days in Kuwait (1970-1985).

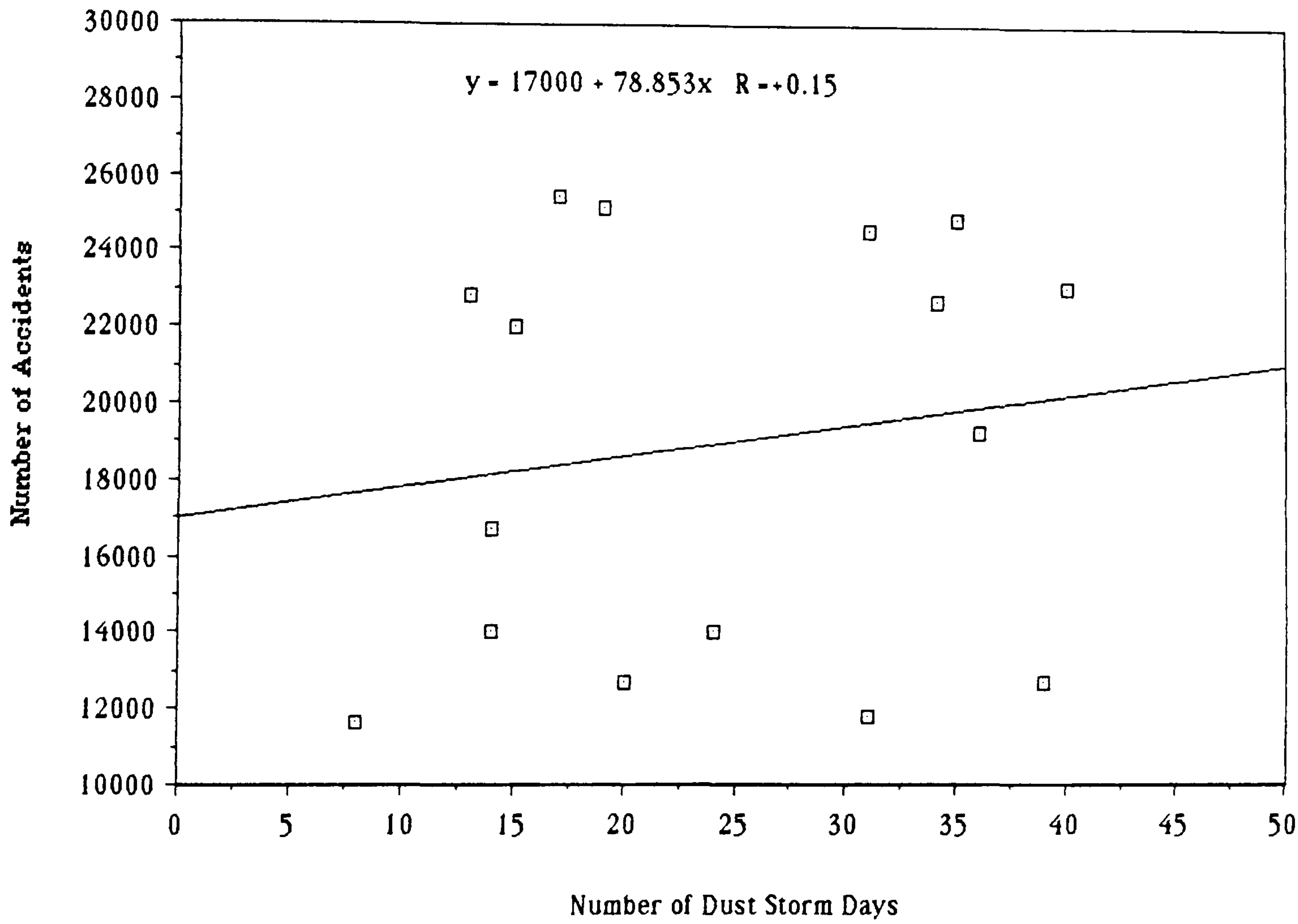


Figure 5-7: Correlation coefficient between the annual number of road accidents and the annual number of dust storm days in Kuwait (1970-1985).

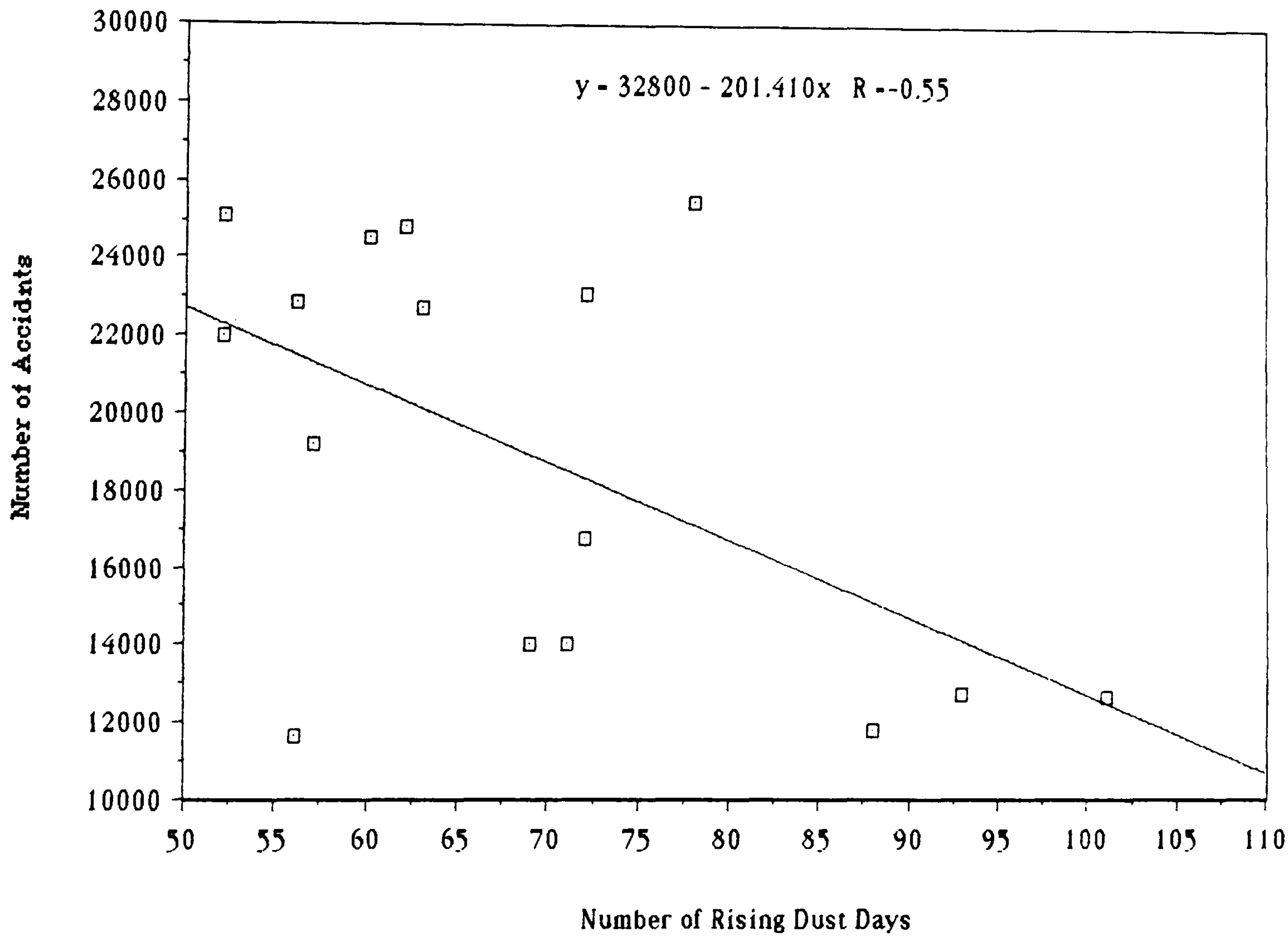
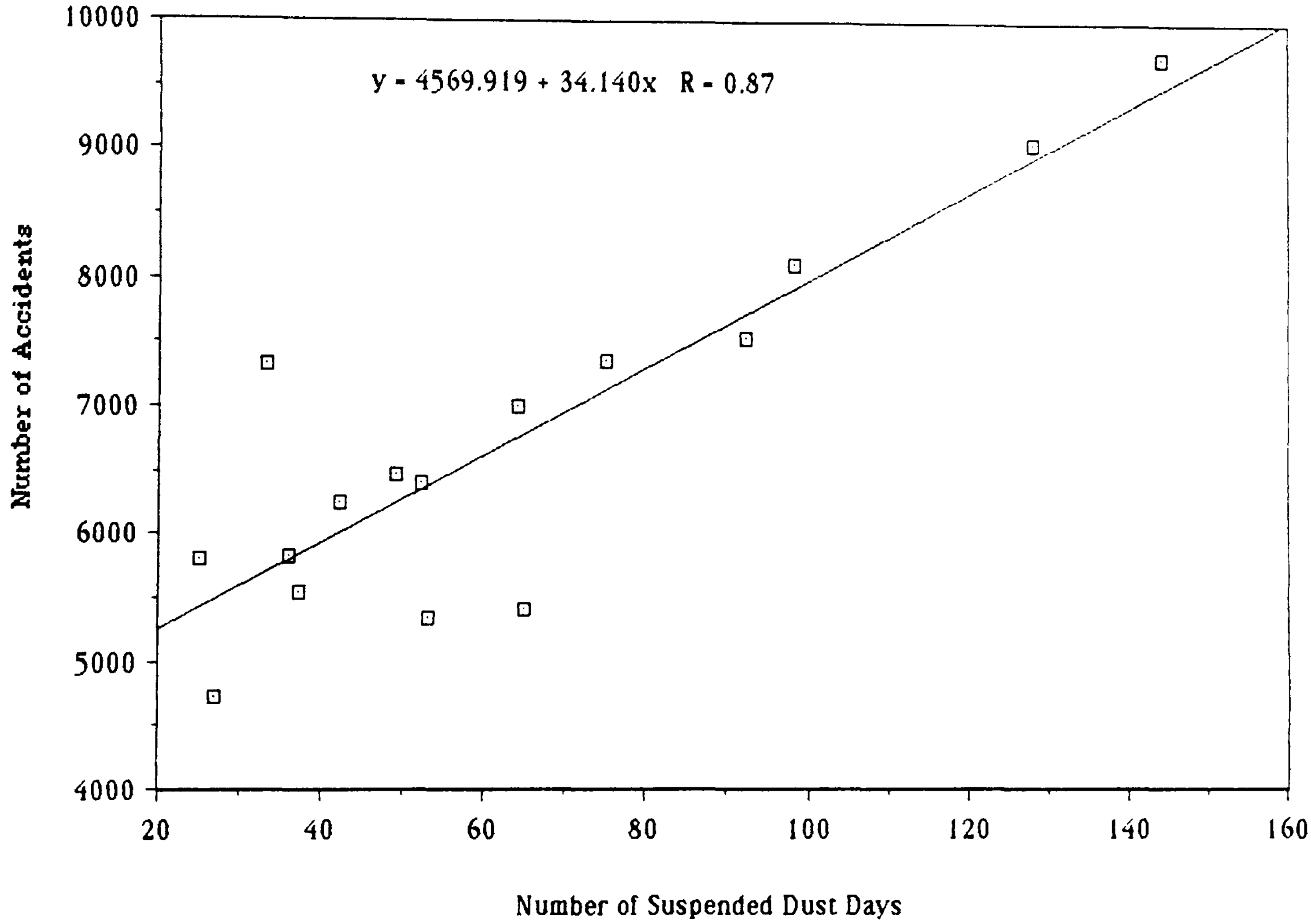
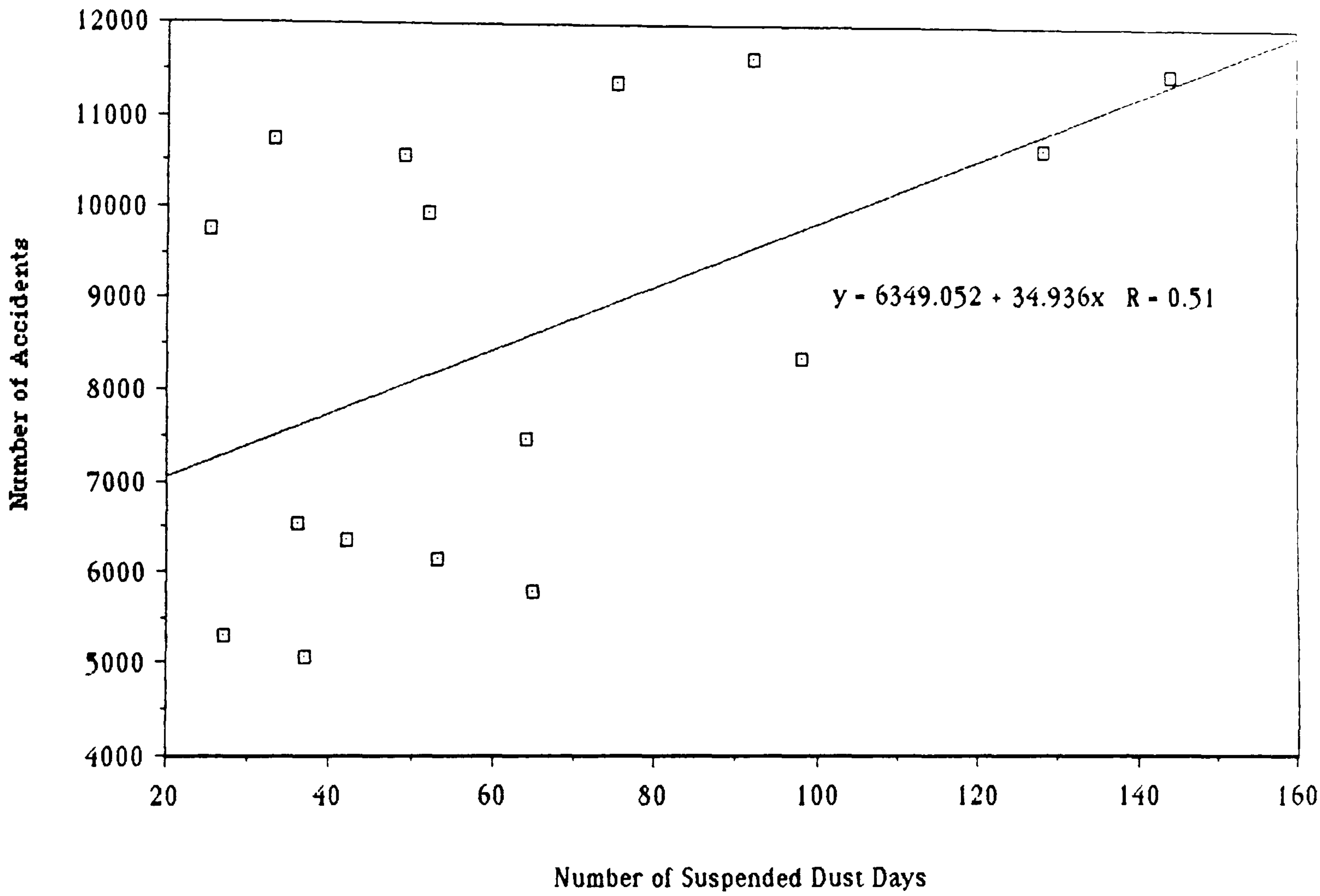


Figure 5-8: Correlation coefficient between the annual number of road accidents and the annual number of rising dust days in Kuwait (1970-1985).



Figrue 5-9: Correlation coefficient between the annual number of road accidents in Capital governorat and the annual number of suspended dust days in Kuwait (1970-1985).



Figrue 5-10: Correlation coefficient between the annual number of road accidents in Hawalli governorat and the annual number of suspended dust days in Kuwait (1970-1985).

There are negative relationships between road accidents in Kuwait's Governorates with the exception of Jahra and visibility range of more than 4 km. Jahra appears to behave differently from other Governorates because it has less pollution than other Governorates. Furthermore data is not available for long duration, so that the trends observed may be due to incomplete records.

Other factors affecting the relationship of road accidents and dust types are:

1) Most roads pass through residential areas, where there are limited open spaces to produce dust. Most accidents occur in these areas. Therefore, the effect of dust will be reduced. Also, most of these roads are relatively near to the coast with an average of 10 km from the shore. Thus, there is not much dust accumulation on the road, unlike roads which are in the desert. For example, workers in the Kuwait Oil Company, travelling into the desert to check oil wells face the full effect of the dust. There are occasions when such people get lost in the desert because of poor horizontal visibility. One incident reported personally, took place in the Burgan oil field, located in the southern desert of Kuwait, about 30 km from Ahmadi City. This is an area empty of people and structure except for oil wells and oil production stations. Therefore sand and dust storms occur frequently. Unfortunately there are no meteorological data available for this area and it is too far from the Ahmadi city for its data to be used. On Sunday 13th July, 1986, a worker in Burgan oil field area Gas Booster Station No. 150 set off toward the Burgan Power Station for the lunch break. It was twelve noon. The distance between the two locations takes about 6 minutes by car. After his eating his lunch with friends he left at 12:30 to return to the Gas Booster Station. For the return journey he took an alternative road which is shorter but not

asphalted. It usually took him 3 minutes. After one minute's driving a severe dust storm arose, created by a strong wind. The horizontal visibility dropped rapidly. As it is unwise to stop the car because it may sink in the sand and may to be difficult for one person to free, he decided to continue driving. He became lost. Fortunately eventually, he came across the main road, but, he did not know how he got there. By this time it was 1:20 p.m., and the whole trip had taken 50 minutes. He was then able to find his way back to the Gas Booster station in Burgan. This is a typical example of how people become lost in the desert because of poor horizontal visibility as a result of dust storms, even though they are familiar with the area.

In the questionnaire, a response about lost direction in the dusty days was sought. Some 89 persons (29.3%) said they had lost direction in the dusty days, 202 persons (66.4%) did not lose direction and 13 persons (4.3%) didn't know **(Table 5.6)**.

	Yes	No.	Don't know
Capital	9	25	2
Hawalli	42	112	6
Ahmadi	22	35	5
Jahra	16	30	-
Total	89	202	13

Table 5.6: Distribution of the respondents loss of direction during the dust storms governorates.

2) Many people travel out of the country during the hot, dusty summer. For instance, the number of passengers departing by air increases during

the summer months as is shown in **table 5.7**. Furthermore this period coincides with school summer holidays. Therefore, road use will be reduced, and the number of road accidents are also reduced.

Months	Scheduled Flights	Non-Scheduled Flights	1983 Departures
Jan.	7.5	2.8	8.1
Feb.	7.8	6.4	9.7
Mar.	7.2	2.5	9.4
Apr.	7.4	1.8	7.8
May	8.9	2.7	6.2
June	10.2	28.0	8.1
July	11.9	25.5	12.8
Aug.	10.4	16.3	11.8
Sept.	7.8	7.7	6.0
Oct.	7.1	1.5	6.6
Nov.	5.8	1.5	6.2
Dec.	8.0	3.3	7.3
	100%	100%	100%

Table 5.7: Percentage of departure passengers in scheduled and non-scheduled flights in Kuwait International Airport of 1984, and percentage of departures in 1983 (Source: Center Statistical Office, p.21, 31,1985)

3) There are other factors which play important roles in road accidents. These include exceeding the speed limit, driving through traffic lights and driving an unroad-worthy car. Such factors increase road accidents even in good weather conditions **(Table 5.8)**.

Months	1985	1986
Jan.	16.8	19.1
Feb.	9.5	20.2
Mar.	9.9	12.2
Apr.	10.4	8.2
May	6.7	2.5
June	5.5	3.0
July	10.9	3.5
Aug.	6.1	7.9
Sept.	5.2	4.7
Oct.	5.7	3.3
Nov.	6.7	3.6
Dec.	6.6	14.4
	100%	100%

Table 5.8: Percentage of all road traffic violations which were exceeding the speed limit in Kuwait in 1985 and 1986. (Source: Annual Statistical Book, 1985, 1986).

4) Road accidents are reported but not related to the type of weather conditions in the time of accidents. Therefore, all factors affect the correlation coefficients and thus effects of the dust types and road accidents can not be singled out.

5) During a severe dust storm the drivers tend to reduce their speed because of reduction in visibility range. Typically these types of dust storms take some time to develop, normally two to three hours. The dust storm generally reaches its greatest severity during the afternoon when most people are at home. Thus, the number of road users are reduced, when dust storms are most prevalent for reasons other than the occurrence of the storms.

According to the data which was collected from the questionnaire survey in early 1987, the following points about dust-related road accidents can be made:

1) There were 20 persons (6.5%) who had an accident during dusty days within the last five years **(Table 5.9)**.

	Capital	Hawalli	Ahmadi	Jahra
Had accident	5	11	2	2
Did not have accident	31	151	61	44

Table 5.9: Distribution of respondents who had an accident during dust storm days by governorates.

There were 60 persons (16.3% of the sample) who had had a road accident within the last five years. This means that one third of the road accidents were dust-related. There were no significant associations between the road accidents and governorate (chi^2=4.91), number of driving years (chi^2=4.33), nationalities (chi^2=1.92) and gender (chi^2=1.71) under degree of freedom of 3. 83.3% of these dust-related accidents were between two cars, 11% were with a solid material such as traffic lights, lampposts, electricity poles, elevated kerbs etc. and 5.6% were cars with people.

Of those reporting an accident within the last five years, there were 80% who had one accident, 15% who had two accidents and only 5% had three accidents.

2) A study of car damage was carried out by the traffic department in Kuwait in relation to road accident injuries sustained. In a sample from the first week of each month for two years 1976-1977 was selected. The

highest age groups who had accidents were 20-24 for both years followed by 25-29 years old and 30-34 years old **(Table 5.10)**.

Age Group	1976	1977
15 - 19	276	350
20-24	895	1143
25-29	794	974
30-34	597	778
35-39	532	629
40-44	237	373
45-49	221	277
50-54	121	135
55-59	37	43
60-64	11	29

Table 5.10: Road accident distribution by age group in Kuwait 1976-1977. (Source: Road Accidents, Traffic Department,p.98-99, 1982).

Generally, the age group between 20-40 is the one most affected by road accidents, because that group represents the active labour force of this society. Therefore, these accidents affect the economy by loss of manpower and by the cost of provision of medical care for these groups **(Table 5.11)**.

Age Group	Yes	No
Less than 20 years	-	-
20-30 years	8	80
30-40 years	8	139
40-50 years	3	53
over 50 years	-	8

Table 5.11: Number of respondents who had a road accident during dust storm days within the last five years.

3) Pertaining to the road type and road accidents in Kuwait, there is not a strong association between road types (motorway, main road and secondary road) and accidents **(Table 5.12)**.

	Motorway	Main Road	Secondary Road
No. of Respondents	11	19	22

Table 5.12: Number of respondents who had an accident in a dust storm and the road type where the accident happened.

The chi-square test result was 3.74 for 2 degree of freedom. Thus, dust storm seems not to have had a strong influence on the road accidents with respect to different road types. This is because most of these roads in Kuwait run through the built up areas. These areas reduce the influence of dust on these roads. But on the other hand, for roads which do not run through a built up area, the effects of dust storm is very considerable. Unfortunately there is no separate data available for accidents on these roads.

4) Regarding the weather types and road accidents on motorways, there is a strong association between road accidents on motorways and weather types (fog, dust storm and rain). The chi-square result was 155.28 for 6 degree of freedom for all weather conditions possible. But if only one tick was used for any of fog, dust storm or rain the result be 15.64 for 2 degrees of freedom. 40.7% of respondents regarded dust storms as a cause of accidents on motorways, 36.5% fog and 22.% rain **(Table 5.13)**.

Weather Types	No. of respondents	% of resp.
Fog	78	25.8
Dust storm	94	31.1
Rain	47	15.6
Fog and dust storm	34	11.3
Dust Storm and rain	7	2.3
Fog and rain	5	1.6
All Weather types	37	12.3

Table 5.13: Number and percentage of respondents stating given weather condition as having an effect on road accidents on motorways.

Thus, the two main weather conditions which play major roles in road accidents on motorways in Kuwait are dust storm and fog, both of which reduce visibility. Rain causes the road to become slippery, and this has an effect on the ability of drivers to avoid road accidents.

5) To specify dust types which have a negative effect on the driver, type of dust has been divided into three categories: dust storm, suspended dust and other types. In this way, it is easy for the respondent to

..distinguish between them, especially the dust storm and suspended dust **(Table 5.14)**.

	No. of Respondents	% of Respondents
Dust storm	237	77.7%
Suspended dust	54	17.7%
Other types	9	2.9%
Dust storm and suspended	3	0.9%
All	2	0.6%

Table 5.14: Number and percentage indicating a negative effect of respondents of the dust types on drivers.

It is noteworthy that most of the respondents claim to be more affected by dust storms than other types. This is because dust storm particles are bigger and remain in the lower layer of the air whereas suspended dust which contains small particles will rise to the upper layer of the air.

6) The following data relate to responses on concentration on road, and controlling the car during the dusty days:

A) Concentrating on the road: **(Table 5-15)**

	No. of Respondents	% of Respondents
Lost concentration	61	19.9%
Did not lose concentration	238	77.5%
Don't know	8	2.6%

Table 5.15: Number and percentage of respondents who replied that they lost concentration on the road during the dusty day.

Most of the respondents lost concentration on the road while dust was blowing, as a result of reduction in visibility. Therefore, during long journeys the drivers became fatigued and they found difficulty in concentration on the road.

B) Controlling the vehicle: **(Table 5.16)**

	No. of Respondents	% of Respondents
Could control vehicle	122	39.7%
Could not control	165	53.8%
Don't know	20	6.5%

Table 5.16: Number and percentage of respondents who could and could not control the vehicle during a dusty day.

About half of the respondents reported difficulty in controlling their vehicles. High wind speeds, associated with rising dust and sand particles from the ground, resulting in reduction of the horizontal visibility range was the main cause. Wind, pulling the vehicles down wind, especially on the roads outside built-up areas where there is no type of wind-break or protection, was the main effect.

There are many factors which play roles in dust-related road accidents. The summer is the most frequent time for the dust phenomena and the relatively high temperature about 45°C, together with dry, dusty, strong winds are all problems. Some drivers, under these conditions, exceed the speed limit to reach their destination in as short time as possible. The complexity of these situations cause road accidents to increase during the main period of dust activity.

Dust-related road accidents need further investigation. In particular data collected from actual dust-related accidents is required. In other words, these is a need for fieldwork based investigation of the road accident cases which happened during the dusty days. Information on dust type, wind direction, wind speed, visibility range, road type and other causes such as driving with speed is required, to be able to understand the causes of accidents during dusty period more fully.

Dust and sand storm particles affect car paint, house paint, plants leaves, and smooth surfaces by abrasion. This effect is more noticeable near the ground than above it. They have been reports that fence posts or telephone poles have shown significant abrasion at ground level (Leet & Judson, 1954). A vehicle moving into the dust-storm increases its effect by it own velocity. Any increase of vehicle speed increases the abrasion process by dust and sand particles. The front parts of the vehicles are more affected than the rear, and outer parts more than the inside of the vehicle. Generally, the affect of dust and sand storms on new vehicles in Kuwait is quite noticeable after two years. The overall effect depends on driving routes. If most time is spent passing through an open area where there is no protection from wind the effect could be seen earlier. A (5)point score techniques (Briggs,1984) has been used to discover which parts of the car are most affected by dust storm **(Table 5.17)**.

Rank	Total Score
1) Front paintwork of Car	1063
2) Windscreen	1057
3) Front lights	971
4) Car paint in general	908
5) Engine air filter	854
6) Car seats	831
7) Car Engine	783
8) Rear window	754
9) Car gauges	663
10) Rear lights	659

Table 5:17 : Ranking of dust effect on cars.

Because the number of respondents differs from one item to another, the parts affected by the dust storms has been ranked by percentage of total score to the maximum score. Because a few of the respondents did not answer one part of the question, or responded "don't know" , because the effects of dust were not clear to them, this means the weighting of some items is affected. Therefore, the result has been reranked as shown in **table 5.18**:

Rank Item	% of total score to maximum score
1) Front car paint	70.4%
2) Windscreen	68.4%
3) Engine Air Filter	67.5%
4) Front Lights	64.5%
5) Car paint generally	60.3%
6) Car engine	57.4%
7) Car seats	53.8%
8) Rear windows	51.3%
9) Car gauges	49.2%
10) Rear lights	47.1%

Table 5.18: Ranking dust effect on car parts according to the percentage of total score to the maximum score.

It is noteworthy that the first two and the last three items do not change in either tables. The two parts most badly affected by dust and sand storms are the front paintwork and windscreen **(Plates 5.2a, 5.2b, 5.3a &5.3b)**. On the other hand, the least affected parts are rear lights, car gauges and rear window.

The front paintwork is the part worst affected by abrasion by dust storm particles followed by the windscreen because these two parts are affected by two contributory forces, wind speed and vehicle speed. This abrasion effect is greater if the vehicle is moving against the wind direction.

It is dangerous to drive a car with its windscreen affected by dust particles especially during night time because the lights of a car coming in the opposite direction are scattered by the windscreen due to the scratches caused by the sand and dust particles which prevents the

Plate 5-2a: A new car on which there has been no dust or sand impact. The car's year is 1988 (picture taken in 1988).

Plate 5-2b: Dust and sand impact is clearly visible on the driver's mirror, front edge of rear mud guard, and the door and window frames. The car's year is 1986 (picture taken in 1988).

Plate 5-3a: Front side of new car (1988) which the front paintwork, headlight, and bumper all in good condition.

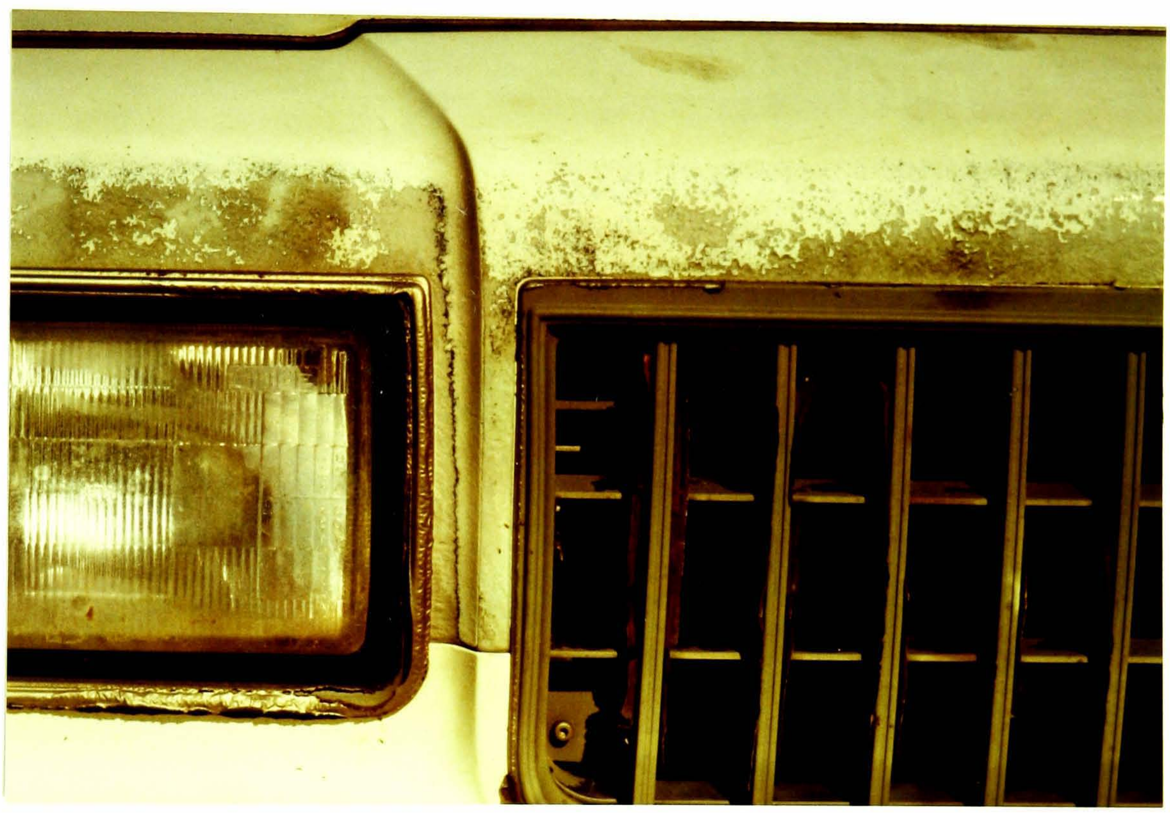


Plate 5-3b: sand storm are clearly visible on the front part of the vehicle (1986). The front paintwork and the headlight glass have been abraded. This abrasion has significant effects on the efficiency of headlight, causing the beam to be scattered. Damage to the paintwork will allow the car's body to be rusted easily.

driver from seeing the road clearly. Further problems are costs involved in maintaining car paint-work and the need to change the windscreen about every four years. In contrast, the effect of dust storm particles are very slight on the rear windows, car gauges and rear lights because these parts are not directly in contact with sand and dust storm particles.

A further part badly affected by dust particles is the engine air filter. It needs to be replaced frequently especially during the dusty season, because it traps dust particles from entering the engine.

The dust storm impacts on cars have been investigated over the four Kuwait governorates **(Appendix II)**. The result are ranked according to percentage of total score to the maximum score to allow easy comparison of the dust impacts between the governorates and so that differences in total numbers for each item from one governorate can be identified **(Table 5.19)**.

Rank	Capital	Hawalli	Ahmadi	Jahra
1.	Windscreen	Front Face Paint	Front Face Paint	Front Face Paint
2.	Engine Air Filter	Windscreen	Engine Air Filter	Windscreen
3.	Front Face Paint	Engine Air Filter	Windscreen	Front lights
4.	Paint generally	Front Lights	Front Lights	Engine Air Filter
5.	Engine	Paint generally	Paint generally	Paint generally
6.	Front lights	Engine	Engine	Engine
7.	Seats	Seats	Rear Window	Gauges
8.	Rear window	Rear Window	Gauges	Rear Window
9.	Rear lights	Gauges	Rear lights	Rear light
10	.Gauges	Rear lights	Seats	Seats

Table 5.19: The distribution of dust storm impacts on the car parts by governorates in Kuwait.

CHAPTER SIX: DUST IMPACTS ON HOUSE

6.1) Introduction:

Not only do dust and sand storm phenomena have an impact on methods of transportation, but they also have an impact on the fabric of houses in arid and semi-arid regions. For example many villages and agricultural lands in the eastern part of Saudi Arabia have been buried by sand movement (Abdul Wahed, 1979).

Dust and sand storm particles play an important role in the erosion process by abrasion. This effect is greatest near the ground level rather than on the upper parts of objects. Leet and Judson (1954) reported many examples of abrasion where the bases of fence posts or telephone poles are abraded at ground level. The vigour of the abrasion process of dust and sand storms depend on:

a) the wind strength associated with the dust and sand, the abrasion becoming more effective during severe dust and sand storms;

b) the hardness or resistance of the objects;

c) the orientation of buildings and constructions, those constructions are which facing the direction of, and in direct contact with dust and sand storms being most affected.

However even with severe dust storms and soft objects, it may be some time before effects are noticeable. Sand storms are more effective and powerful erosion agents than dust storms due to larger size of the sand particles and higher wind speed.

6.2) Dust and Homes in Kuwait:

There are no previous studies about the environmental impact of dust and sand storms on houses in Kuwait. Most of the studies of dust storms which have been made concentrated on the physical side of the phenomenon, and even such studies are relatively recent. The reason for this that there was no scientific research centres or institutes for study of the environmental hazards of dust storms until the early 1960's. After the establishment of organizations such as University of Kuwait, Kuwait Institute for Scientific Research, Kuwait Foundation for the Advancement of Science, Environment Protection Council, Environmental Society, all of which are concerned with environmental dust storm hazards in Kuwait such studies have increased. However as the studies carried out by these organisations were concentrated with the physical side of the problem, there is a shortage of published knowledge and information about dust storm environmental impact on houses. Dust environmental impacts on houses and buildings need a comprehensive study to measure the degree of the dust hazard, and to give some recommendations on reduction of the hazard degree.

In order to measure the degree of dust hazard affecting houses in Kuwait, a questionnaire using five point score method was adopted (Briggs, 1984). The degree of hazard was scaled from one (very little impact) to five (very severe impact), to assess which house parts are most affected by dust storms. A total score was calculated for each part, to find out the part most affected by dust. The highest score presents the house part which is most badly effected by dust. The number of respondents differs from one question to another, because a few of them did not answer all parts of a particular question. This means that total scores may not be accurate. To standardize scores, percentage of the maximum possible was used to measure the degree hazard. House parts affected were then ranked by the percentage of actual score to maximum possible score

6.3) Dust Impacts on House:

Dust storms have a greater effect on the exterior of the house than the internal parts **(Table 6.1)**.

Rank	House Parts	% of Total to Max. Score
1	Exterior Windows	67.1
2	House garden	66.9
3.	Exterior house paint	60.6
4.	Water tank	60.4
5.	Carpets	57.5
6.	Furniture	57.4
7.	Exterior door paint	57.2
8.	Living room	55.4
9.	Electrical equipment	52.5
10.	Bedroom	50.5

Table 6.1: Ranking of the house parts affected by the dust storm in Kuwait.

General characteristics of table 6.1:

1) The first four items, which cover the areas by dust storms, are all exterior features. There are directly subjected to the effect of dust storm. Here, the dust impact can be noticed easily.

a) Exterior windows: Ninety five point four of the respondents consider this part the part of the house the most affected by dust storms. Dust impact on the exterior windows are noticed easily. Those windows which face the direction of dusty wind are particularly affected. These windows are also the main way dust enters the house. Small dust particles stick to the windows whilst bigger particles are deposited on the edges of window-frames. Therefore windows need to be cleaned frequently, especially during dusty period. This takes time and use of water. The increase of water use resulting from dust is considered later.

b) Household Gardens: Dust has a harmful effects on the plants, due to its deposition on plant leaves. This reduces the amount of sunlight reaching the leaves and blocks stomata, hindering photosynthesis.

Qasim, (1986) discussed an experiment in Al-Hasa, Saudi Arabia, where the palm trees were under observation for about two years. In particular the front of these palm trees were observed with regard to the size, colour and taste of the dates. Two groups of palm trees were involved in this experiment. One group was near to a sandy road, and the other group, further away. The one close to the sandy road was affected by dust particles from the road. Dates were smaller in size, differed in colour and taste, and the date pits were smaller than those of the other palm tree group.

Specialists in the Agricultural Department of Kuwait have stated that dust and storm particles may abrade the surface layer of the plant leaves. This abrasion of the surface layer of leaves increases the evapo-transpiration, which means the leaves will lose a lot of moisture, and may wilt and die. This occurs mainly in small plants rather than larger trees (Agricultural Department, Kuwait, Pers. Comm. 1986), abrasion is stronger near the ground where larger dust or sand storms particles are mainly found. In the Negev Desert, potato and tomato plants have been affected by Alternaria blight due to sand and dust storms. This disease may be a serious problem in the agriculture zone of the Negev, when the plants can be completely desiccated, especially as the agricultural area of Negev is surrounded by desert on the east, south, amd southwest. Southwestern winds develop over poorly vegetated land and cause sand and dust storms to occur (Rotem, 1965). Within the Negev in the agricultural centre under study, during the worst epidemics, 70-100% of the foliage was destroyed. Sand and dust storms were frequent and strong in this location. It was found also that the disease incidence decreased to 30-50% along the route from the centre to the almost storm-less area (Rotem, 1965).

c) Exterior House Paintwork: Like the car front paintwork, exterior house paintwork is affected by dust and sand storms. But the effect of abrasion on exterior house paint takes longer than for the car front paintwork. This is because, in the case of the car, its velocity may add to that of the sand or dust particles. Therefore, the effect will be increased and is more quickly evident. The degree of dust environmental impact on exterior house paintwork is dependent on several factors:

i. House orientation: the effect of dust is stronger on houses which facing the direction from which the dust blows.

ii. Frequency and Severity of dust storms: more frequent and severe dust storms cause greater impacts on exterior house paintwork. With increased frequency, dust particles have a longer duration to abrade the paint. With greater severity, dust particles have more power to abrade the house paint.

iii. House Protection: protection means reduction of the dust hazard by construction of windbreaks or solid fences around the house. These reduce wind speed around the actual house and therefore the severity of dust storms will be reduced.

d) Water Tanks: In most homes in Kuwait the water tanks are located outside on the top of the house or on the top floor of the apartment building. **(Plate 6.1)**. Generally there are no roofs above these tanks. Therefore, they are subjected directly to dust storm action and, especially to the accumulation of fine particles. Fine particles enter and are deposited in the water tanks thereby polluting the drinking water. By accumulating with in the tank, they block it up so that after a few years the whole water tank may need to be replaced.

2) The last three house items, which are rather less affected by dust storms are bedrooms, electrical equipment and living rooms. None of these have a direct contact with dust storms.

a) Bedroom: There is not much direct dust effect on bedrooms, because they are used for sleeping, so they are mostly used during the nighttime when the dust storms are less active. Also, the room curtains which are kept closed most of the time, help to protect the bedroom from the entry of fine dust particles. Therefore the impact of dust storms on bedrooms is low.

b) Electrical Equipment: Dust particles may enter the inside of these where they have more a serious effect than on the exterior. Inside dust particles may be less evident, so that therefore the dust hazard on these equipment may not be judged so accurately, and is therefore not given a high rating by questionnaire respondents.

c) Living Room: The most commonly used rooms in the house are living rooms. Because they are used every day, they are cleaned and vacuumed daily. Therefore, most of the dust particles deposited in the living room are removed daily, and major accumulations do not occur.

6.3.1) Dust Impact on House by Governorates: (Appendix II)

The capital and Hawalli governorates are alike, in that they are largely built up. Thus there are no extensive area of bare ground in the two

Plate 6-1: Water tanks on the top of houses in Subahiya city, allowing dust to be deposited in these water tanks. These tanks are used to store drinking water. Also, notice the second house on the left, in which the balcony having been blocked and replaced by a window.

governorates. On the other hand, Ahmadi and Jahra governorates have large areas of desert. The northern desert forms part of Jahra Governorate (10964.4 km^2) and the southern desert is part of Ahmadi governorate (4933.5 km^2) **(Table 6.2)**.

	Capital	Hawalli	Ahmadi	Jahra
1.	Exterior Window	House garden	Exterior window	Exterior window
2.	House garden	Exterior window	House garden	House garden
3.	Exterior house paint	Exterior house paint	Carpet	Water tank
4	.Water tank	Exterior door paint	Furniture	Furniture
5	Exterior door paint	Water tank	Exterior house paint	Carpet
6	Living Room	Furniture	Living room	Exterior house paint
7	Furniture	Carpet	Water tank	Exterior door paint
8.	Electric Equipment	Living Room	Exterior door paint	Living room
9.	Carpet	Electric Equipment	Electric Equipment	Electric Equipment
10.	Bedroom	Bedroom	Bedroom	Bedroom

Table 6.2: Ranking the environmental impact of dust on parts of the house by governorates in Kuwait.

General points from table 6.2:

1) Exterior windows and the house gardens seem to be highly affected in all the governorates

2) The two areas least affected by the dust in all governorates are bedrooms and electric equipment.

3) The first five items in Capital and Hawalli governorates are similar. These are, Exterior windows, garden, exterior house paint, water tank and exterior door paint. This is because the two governorates have a similar geographical location, and dust storms affect them generally in the same way.

4) Dust storm effect on furniture and carpets are higher in Ahmadi and Jahra governorates than the Capital and Hawalli governorates.

For further investigations on dust storms effects on house parts by governorates, chi-square tests were used to find out which parts of the house have a significant difference between governorates.

Generally there is no significant difference between governorates of effect of dust storms on house part, except in case of carpets and bed rooms. Bed rooms are more significant than carpets through-out the governorates of Kuwait. Carpets can not be considered as an effective indicator of dust effect, because there are many types and qualities of carpets. In case of good carpet quality, people take more care of it than cheaper quality. Also, the cleaning methods have effects on the assessment since people who use a broom to clean the carpet notice dust on the carpet more than whose using vacuum cleaners. Also it was found that the carpets are affected by the house type. Generally the people who are living in middle and high class villas, use good quality carpets and care more about them than people who live in flats, or limited income houses. Therefore, it is difficult to use carpets as a measurement or an indicator of dust effect.

In case of bed rooms, the situation is different from carpets since bed rooms are not effected so strongly by notions of quality. Also, bed rooms have more significant differences than the carpets through-out governorates. The areas where dust storms are more frequent and intensive have high amounts of dust deposited. The governorates which are closer to the desert such as Ahmadi and Jahra are more affected by dust storms and so, bed rooms there are more effected. The effect on bed rooms is also related to the role of females who take care of removing dust deposit and cleaning the bed rooms.

6.3.2) Dust Effect on House by the House Type :

The three most common house types in Kuwait are villas, traditional or limited income houses and apartment buildings. Villas are modern buildings which are mostly built to European design. Traditional houses are one floor buildings with an internal courtyard. Limited income homes are provided by the governorate for people with low incomes. Most of these houses are also one-floor buildings, with an internal courtyard **(Table 6.3)**.

Rank	Villa	*House	Flat
1	House Garden	House Garden	Exterior window
2	Exterior window	Exterior window	House garden
3	Exterior house paint	Furniture	Water tank
4	Exterior door paint	Carpet	Exterior door paint
5	Water tank	Living Room	Exterior house paint
6	Furniture	Exterior house paint	Carpet
7	Carpet	Exterior door paint	Furniture
8	Living Room	Water tank	Living room
9	Electric equipment	Electric equipment	Electric equipment
10	Bedroom	Bedroom	Bedroom

Table 6.3: Ranking the effect of dust on house parts by house type in Kuwait
*House: traditional and limit income houses

General points from table 6.3:

1) The dust impact on the first two items, gardens and exterior windows, are the same for all house types. These are highly affected by dust storms regardless of the house type, due to the exposed location of these features. This is explained by these two items forming the first contact

with dust particles, so that dust particles are deposited and stick on the exterior windows and plant leaves very readily.

2) The effect of dust on the last two items, electric equipment and bedrooms, are the same for all house types. These two items are least affected by dust storms regardless of the house types, due to the protected location of these items within houses.

3) Furniture, carpets and living rooms seem to be affected by the dust storms to the same extent. They came in a consecutive sequence for each house types, though with different rank levels between types. The effect on these items is therefore intermediate.

In the case of villas and flats, furniture, carpets and living rooms have the same level of effect. They occupied the sixth, seventh and eighth rank level. But in the case of traditional and limited income houses, dust storms have a stronger effect than for villas or flats reaching the third, fourth and fifth rank level. That because most of villas and flats are located in the build-up area and are in privately owned, allowing the owner to select the location. The limited income houses, provided by the government, mostly are built in a previously unbuilt area, in order to establish new settlements.

A further analysis to examine the role of dust on house parts by house types, using the chi-square test, was carried out. This method was used to find out if there are significant differences in the effects of dust storm on house parts by house types. In fact most part of the house have significant differences according to house types, however other factors play roles including number of balconies, open spaces around buildings, whether there is a garden, and if so whether it contains tall or short trees. The house parts which show most significant differences are:

1) Water Tanks: These are most affected by dust deposits which contaminate drinking water. There are many tanks on the top of each

building, each of which belongs to one flat in the building. Flats tanks are most effected because they are located on the top of buildings and in many cases their covers are left open allowing dust to enter. After a few years the tank needs to be changed due to the accumulation of thick mud in the bottom, which contaminates the water. In case of villas the people show more concern. They build a protection cover to prevent dust from entering and to give protection from sun's heat.

2) Electric Equipments: These equipments such as television or radios are influenced by fine dust particles which enter the equipment and affect their function. Also, use of these items are related to gender. Women are mostly responsible for exterior cleaning, but for repairing and fixing electrical equipment males are in charge.

3) Carpet: In the case of the effect of dust on carpets, the quality of carpet is involved. Thus people who live in flats are generally less concerned about the carpet quality. On the other hand, those who live in villas are more concerned about the effect of dust due to good carpet quality. Many working class people live in flats. Buildings with gardens, villas and houses, have carpets which are less affected by dust.

4) Furniture: In case of household furniture as for carpets quality is involved. The effect of dust on furniture is influenced by the occurrence of open space around the house which acts as a local dust source. Also it is related to the occurrence of gardens around the buildings, villas and houses, since those buildings with gardens are less affected by dust because of protection provided by the garden.

5) Exterior Door Paint: Villas' and houses' exterior doors are more affected by dust storm than flats, because flats do not have main door entrances like villas and houses, as the doors of flats are inside the building where they have protection. Limited income houses and

traditional houses are more influenced by dust storms than villas. Mainly villas have a garden around the villa which protects the exterior door paint. Protection is also related to the height of trees; those gardens with tall trees being more able to reduce dust effects than those with short ones.

6) Exterior House Paint: Dust and sand storms act as an erosive agent on house paint. Limited income houses are more affected than villas, because these houses have been built in new town developments where dust and sand storms occur more frequently. This factor is also related to gender, because males are more concerned about repainting their house as this is generally regarded as their job.

7) Exterior Window: The exterior windows of limited income houses are more influenced by dust particles. These stick on the windows and dirty them. Villas' exterior window are less affected due to the garden around the villa. Dust on windows is influenced by the open spaces around the building which act as a local dust source. Females are more concerned about this problem because it is they who generally clean the house, including the windows.

8) Living Rooms: The parts which have least significant differences of the dust effect related to house types are living rooms. Living rooms are less affected in villas and flats because they are closed buildings and located within the built up area. But the limited income and traditional houses suffer from the dust hazard in their living rooms. That is because such houses have been built in open areas close to the desert, in new towns. These dust differences have a gender component because females generally have the responsibility for looking after the house.

6.3.3) The Impact of Dust on Houses in Relationship to Gender of Respondent:

An analysis of the relative effects of dust on different parts of the house show there responses are related to the gender of respondent; females have over all responsibility for the state of the house whilst males make good any damage done **(Table 6.4).**

Rank	Male	Female
1	House garden	Exterior window
2	Exterior windows	House garden
3	Water tanks	Exterior house paint
4	Exterior house paint	Water tanks
5	Carpets	Furniture
6	Furniture	Exterior door paint
7	Exterior door paint	Carpets
8	Living Room	Living Room
9	Electric Equipment	Electric Equipment
10	Bed Rooms	Bed Rooms

Table 6.4: Ranking of dust storm hazards on household parts by gender in Kuwait.

The main points relating dust impacts on house by gender are:

1) The first four items have the same priority among the males and females. They agreed on the items but not on the ranking order. The items are, exterior windows, house garden, exterior house paint and water tanks. As has been discussed previously all of these items are highly affected by the dust storms.

2) The last three items, which had least impact by the dust storms, have the same ranking order and priority among males and females. Therefore,

there is very little overall difference in the perception of the effect of dust upon their houses between men and women.

Additional investigation was carried out using chi-square test to find out the items which have significant differences related to gender. There are five items which show significant differences:

1) Three items are related to the female role in the house. They are exterior windows, living rooms, and bed rooms. The females look after these items more than males. They have general responsibility for looking after the house and cleaning it, so they are more likely to know about dust effects on these items more than males.

2) Exterior house paintwork is a typical male job , and men are generally concerned with maintaining and repairing the house. Therefore, they have more information on effects of dust on these parts.

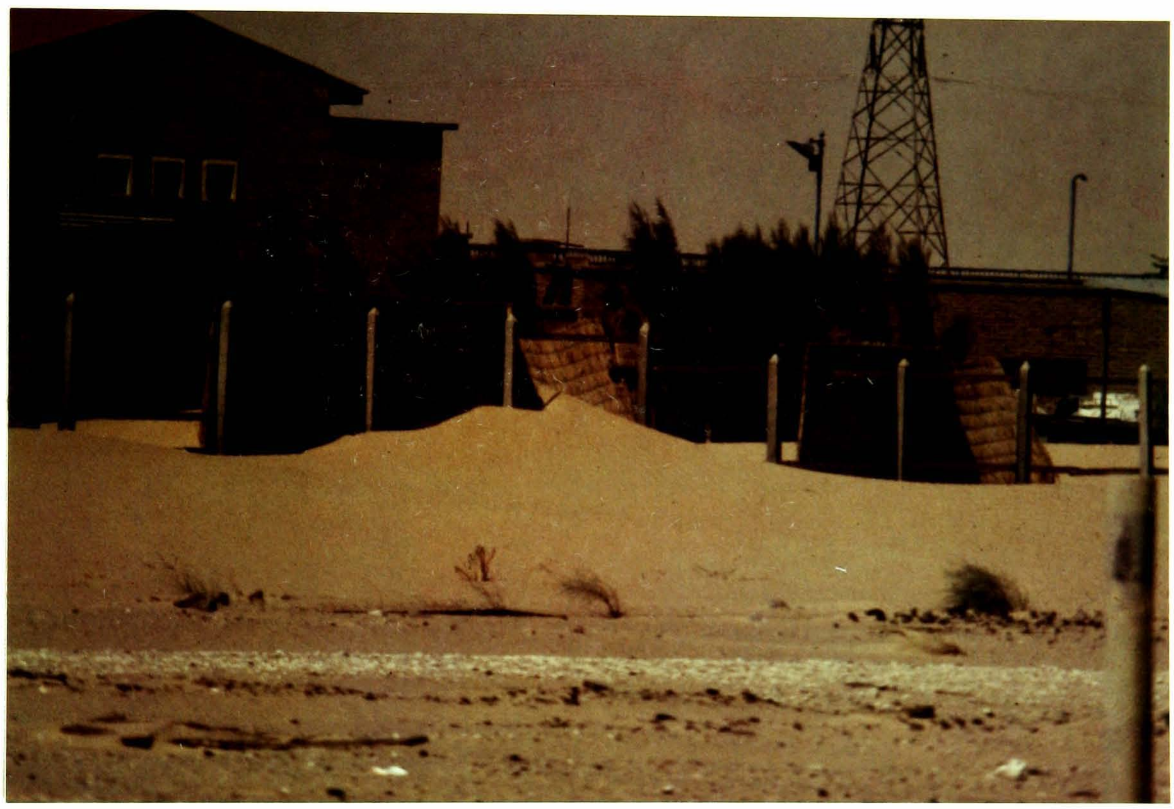
3) In the case of electric equipment both males and females look after them, but from different points of view. The females are responsible for cleaning them whilst males take care of repairs.

6.4) Dust Impact Factors on Houses:

There are many factors involved in dust storms and their impact on houses. These factors in some cases cause an increase in dust impacts on homes, and in some cases a decrease. There are three factors within the residential areas in Kuwait, which are most noticeable:

1) Open uncovered spaces (bare lands) : Originally these spaces were left as "green lungs" in residential areas or some areas facing the desert **(Plates 6.2 & 6.3)**. However some of these areas have been left uncovered by plants or grass and thus play an important role in producing or supplying dust to the dust storms. Furthermore these open spaces allow wind a chance to accelerate, after being reduced by surrounding buildings. Open areas are distributed over all Kuwait.

Plate 6-2: Petrol station outside Ahmadi city, facing west. It has been affected by north westerly winds carrying sand from desert. This petrol station is located in an open area, facing Ahmadi desert. There is no wind break protection for this station. During severe sand and dust storms change of car's oil and oil filter in this station is not recommended.



<u>Plate 6-3:</u> Face of police station in Ahmadi city, which has been broken down due to the weight of sand trapped by this fence. This police station is located at the outside of Ahmadi city and facing sand and dust storms blowing from Ahmadi desert.

(**Table 6.5**).

Respond	Capital	Hawalli	Ahmadi	Jahra	Total
Present	25	141	52	48	266
Not present	13	46	14	16	89

Table 6.5: The distribution of open areas around the building, according to the respondents answering to a question on presence of open areas around their buildings.

A total of, 96.2% of the sample replied either "yes" or "no" and 3.8% did not reply. Of those responding 74.9% replied that there were open areas around their building, 25.1% replied there were no open areas around their building. **(Table 6.6).**

Respond	Capital	Hawalli	Ahmadi	Jahra	Total
Produce dust	19	104	43	45	211
Not produce dust	10	45	14	7	76
Do not know	-	4	1	1	6

Table 6.6: The respondents distribution by governorates on whether open areas produce dust.

Of the total 72% stated that these open areas stimulated dust production in the surrounding areas, whilst, 25.9% stated that these open areas do not produce dust. Only 2.1% stated that they did not know.

2) Role of Balconies in dust impacts: There are many ways that dust particles can enter the houses and balconies are one of the most important entry points. The more balconies in buildings, the greater the

possibility of dust particles entering the buildings **(Table 6.7)**.

No. Balcony.	Capital	Hawalli	Ahmadi	Jahra	Total
One	4	61	16	27	108
Two	1	24	5	5	35
Three or more	1	7	3	6	17
Total	6	92	24	38	160

Table 6.7: Distribution by governorates of the number of balconies in respondents houses.

Most of the respondents (57.5%) who have balconies in their houses live in Hawalli governorate. This is because Hawalli governorate includes many of the apartment buildings. Most of these buildings are found in three main localities, Salmiya, Farwaniya and Hawalli. Of the total 67.5% of respondents reported one balcony, 21.9% two balconies and 10.6% three or more than three balconies in their houses. The number of balconies increases the amount of dust which enters the house **(Table 6.8)**.

Response	Capital	Hawalli	Ahmadi	Jahra	Total
Increase dust	8	83	26	38	155
Did not increase dust	1	18	8	6	33
Don't know	-	4	1	-	5

Table 6.8: The respondents distribution by governorate in Kuwait reporting that presence of balconies increased dust entering their house.

Overall 80.3% of respondents agreed that balconies played a role in dust entry to the home, and only 17.1% of respondents did not agree on that role.

3) Role of Gardens in Dust Impact: In this case the two main parts of dust storm phenomena involved are the occurrence of dust particles and fresh wind. The amount of dust particles in the air and wind speed can be reduced by trees. Furthermore plants play a major role in soil stabilization, and this may complement their role as wind breaker in reducing the wind speed. So, the importance of green land lies in its ability to reduce the activity of dust particles, and particularly for trees to lower wind speed. About half of the sample (49.1%) have a garden around or within their houses (ie. courtyard gardens) **(Table 6.9).**

Response	Capital	Hawalli	Ahmadi	Jahra	Total
Have garden	18	87	39	26	170
Do not have garden	19	95	28	34	176

Table 6.9: Distribution gardens, around or within the house in Kuwait.

Gardens play an important role in reducing the amount of dust which enters the house. 68% of respondents stated that gardens have a major role in reducing the amount of dust which enters their houses. Only 25.6% of respondents stated that the garden has not caused dust reduction **(Table 6.10)**.

Respond	Capital	Hawalli	Ahmadi	Jahra	Total
Yes	11	59	26	21	117
No	6	23	11	4	44
Don't know	2	4	2	3	11

Table 6.10: The distribution of respondents in Kuwait regarding the role of gardens in reducing the amount of dust entering the house.

Tall trees are efficient in reducing the amount of dust entering houses through its effect in reducing wind speed **(Table 6.11)**.

Trees	Capital	Hawalli	Ahmadi	Jahra	Total
Tall	13	35	19	21	88
Short	5	45	19	7	76

Table 6.11: Distribution of respondents in Kuwait, having tall or short trees around their homes.

For instance, in the case of Jahra governorate, it is clear that tall trees help a great deal in dust reduction, as dust occurs more frequently because of the proximity of desert. From Tables 6.10 and 6.11 it can be seen that there were 75% of Jahra governorate respondents who stated that the garden has an important role in dust reduction. Also, 75% of Jahra respondents stated that they have tall trees around their houses.

6.5) Dust and Energy and Water:

The consumption of both electricity and water (both fresh and brackish) increases during the summer months to a maximum. There are two main factors which affect the consumption of electricity and water which are temperature and dust. Also, there is a significant interrelationship between temperature and dust. For example there are significant correlation between dusty days and mean of temperature (r=+0.75) **(Figure 6-1)**; and dust storm days (r=+0.5) **(Figure 6-2)**. The explanation for this relation is that both, temperature and dusty days, reach their maximum value in summer. But it been found that temperature has a more significant influence and correlation than dusty days and dust types. It seems that strong winds which are associated with dust reduce the feeling of heat. Dust clouds also reduce and scatter the sun light which are received by the earth. There are strong correlation between brackish water (r=+0.86), electricity (r=+0.84), and fresh water (r=+61) with temperature. This is explained by people using more brackish water for watering the area around their houses and for irrigating trees. During summer trees are given water many times, due to the high amount of evaporation. During hot summer days people use air conditioning more continuously, and therefore consumption of water and electricity are increased.

1) Energy:

During summer most people stay within their houses for two main reasons. First, summer weather is extremely hot with the temperature reaching about 45°C during day time. Second, dust storms are more frequent during summer, especially during the day time. So the hot, dry and dusty summer keeps most people inside their house. Therefore, they tend to use air conditioning continuously in order to protect themselves from these condition and so energy consumption is increased during this time **(Table 6.12)**.

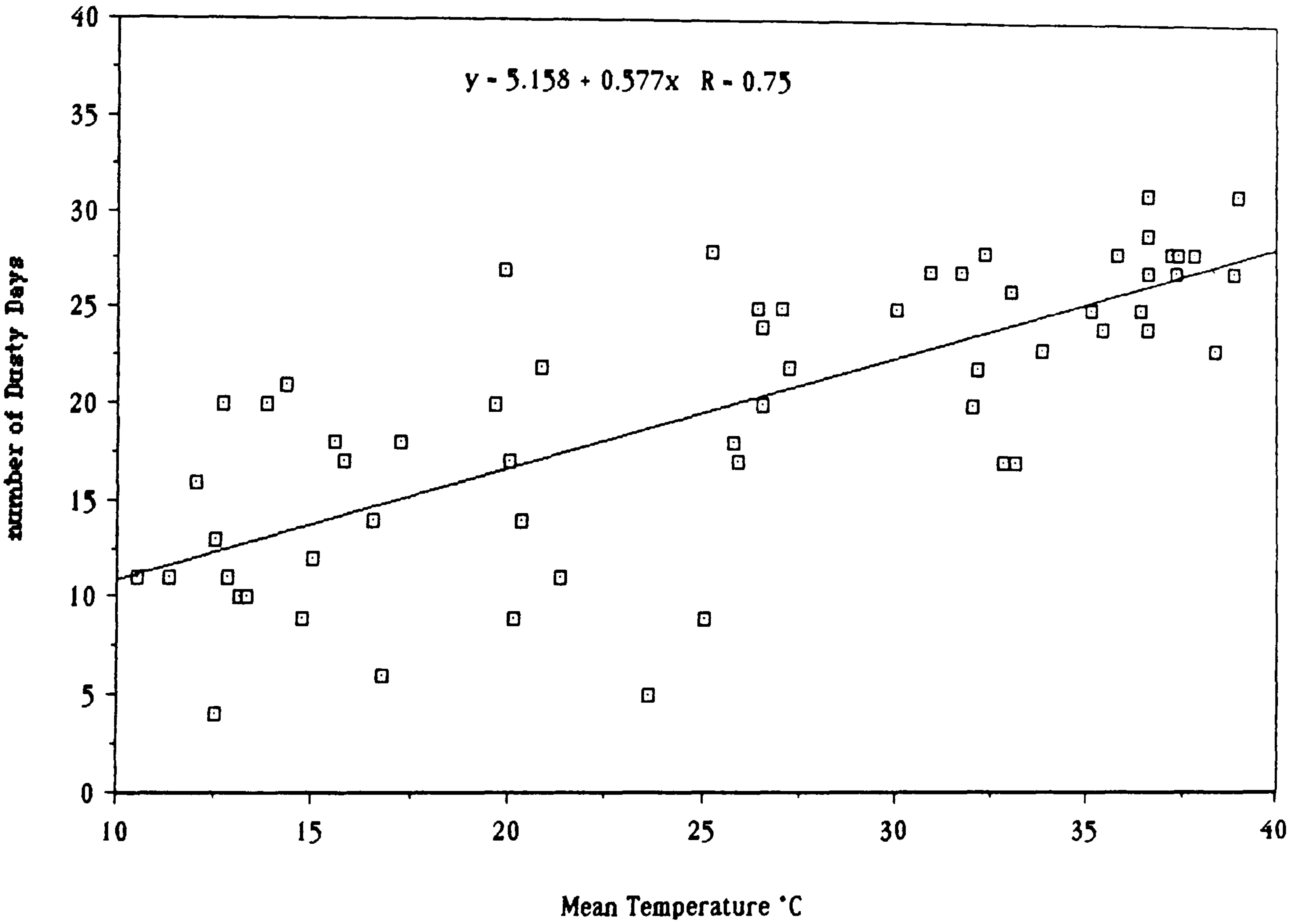


Figure 6-1: Correlation coefficient of total monthly of dusty days and monthly mean temperature °C from 1980 to 1984 in Kuwait.

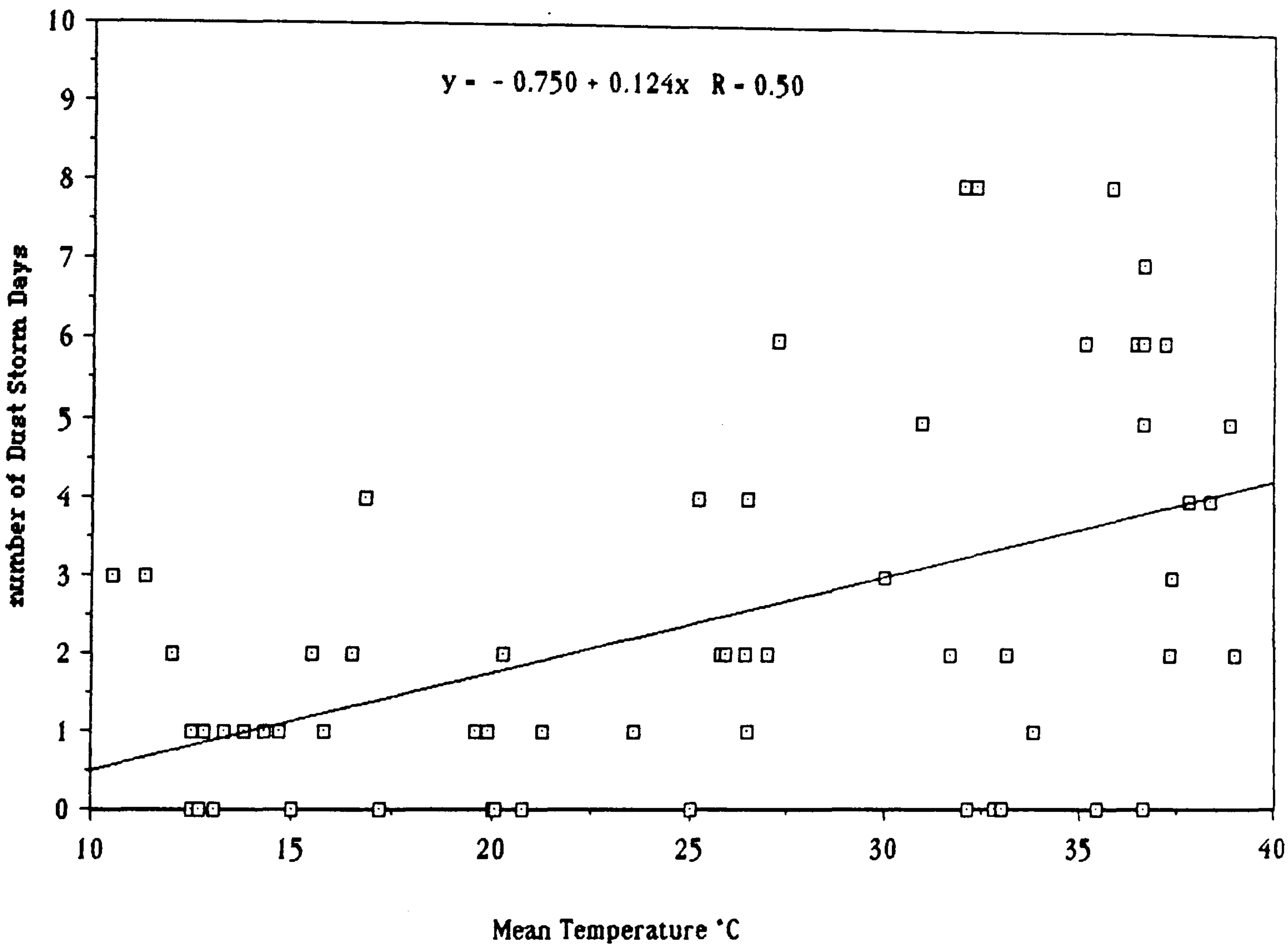


Figure 6-2: Correlation coefficient of total monthly number of dust storm days and monthly mean temperature °C from 1980 to 1984 in Kuwait.

Month	1980	1981	1982	1983	1984
January	770.0	772.5	887.5	1067.5	1072.5
February	752.5	760.0	922.5	977.5	1062.5
March	672.5	675.0	752.5	792.5	940.0
April	892.5	1030.0	1240.0	1100.0	1345.0
May	1295.0	1392.5	1715.0	1740.0	1870.0
June	1610.0	1717.5	1950.0	2177.5	2337.5
July	1595.0	1892.5	2097.5	2252.5	2512.5
August	1430.0	1775.0	1955.0	2137.5	2270.0
September	1330.0	1595.0	1910.0	1950.0	2135.0
October	1935.0	1262.5	1460.0	1517.5	1695.0
November	652.5	845.0	870.0	1015.0	1157.5
December	747.5	755.0	1037.5	1015.0	1225.0

Table 6.12: The monthly average of electricity peak load in Kuwait 1980-1984 (Mega watt).

It is noteworthy that in March the average electricity peak load decreases due to more pleasant weather conditions. During this month in Kuwait, there is no need to use either heating or cooling equipment.

There is a significant relationship between the monthly average of electricity peak loads, and monthly average number of dusty days. **(Table 6.13, Figures 6.3, & 6.4).**

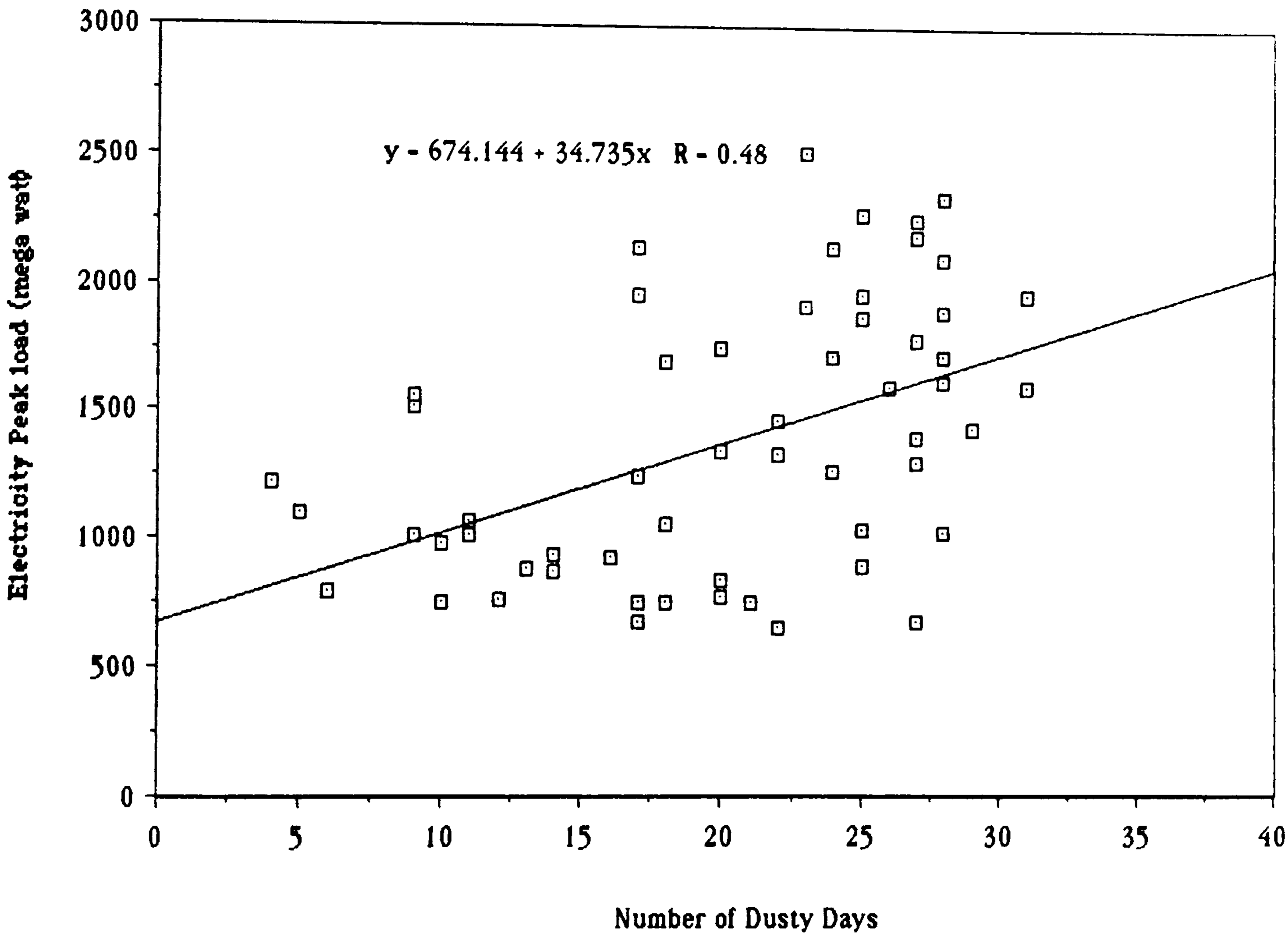


Figure 6-3: Correlation coefficient of monthly average of electricity peak load (mega watt) and monthly total number of dusty days from 1980 to 1984 in Kuwait.

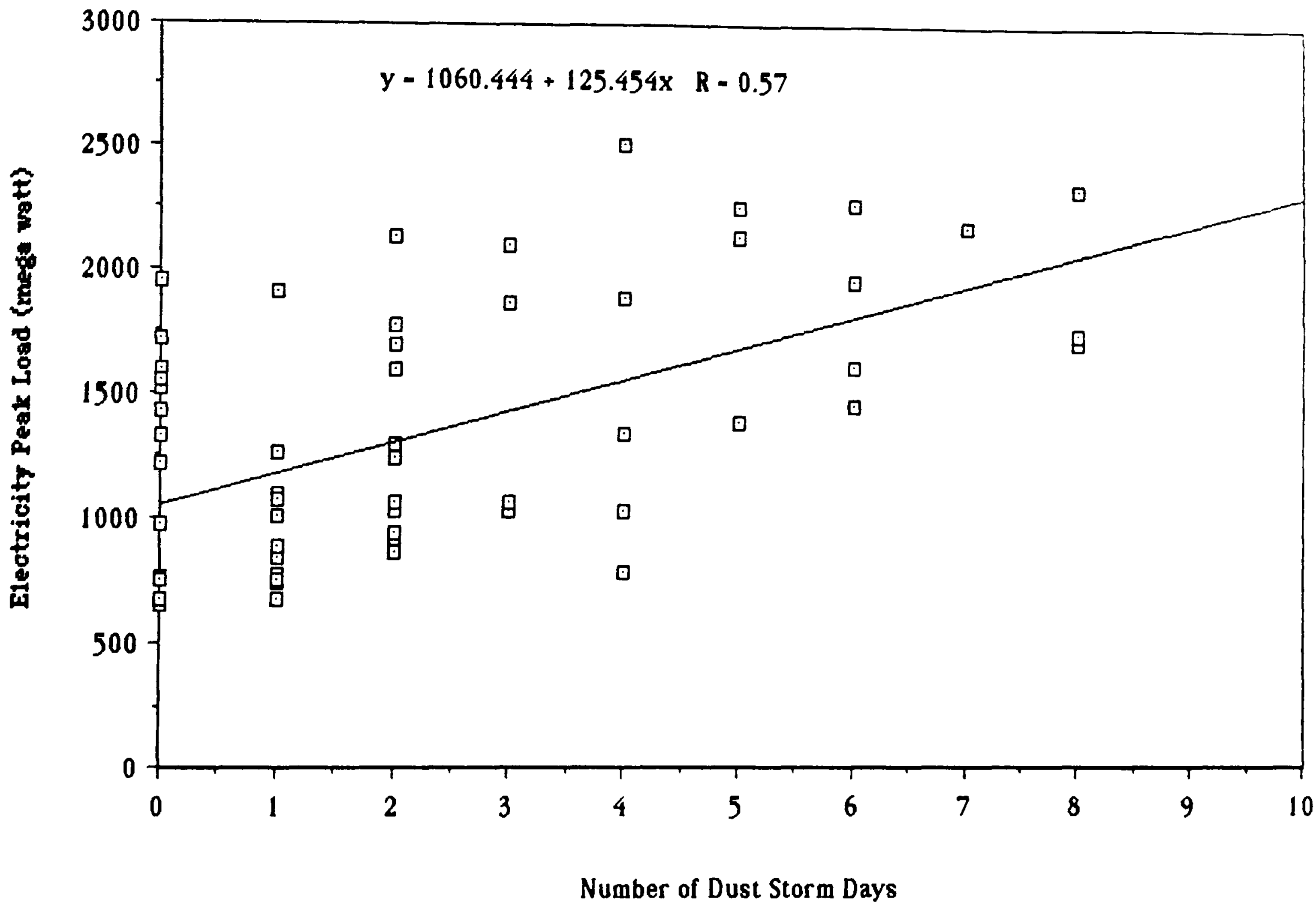


Figure 6-4: Correlation coefficient of monthly average electricity peak load (mega watt) and monthly total number of dust storm days from 1980 to 1984 in Kuwait.

	Dusty days	Dust storm days	Rising days	Suspended dust days	Hazy days
Electricity load	+0.503	+0.580	+0.452	+0.148	+0.055

Table 6.13: Correlation coefficients between the monthly average of electricity peak load (mega watt) and the monthly average of number of dust type days in Kuwait 1980-1984 (n=60).

But the temperature has a stronger relationship than dust type with use of electricity, the correlation coefficient between the monthly average of electricity peak load and the monthly temperature average being +0.847 (n=60) **(Figure 6.5)**. By using multiple regression the t-ratio of temperature is find to be the highest. The multiple regression between electricity load and dust types is r=+0.657, but is increased to r=+0.899 by adding temperature. By omitting the affect of the three winter months (January, February and December (n=45)) the correlation coefficient become even higher r=+0.919; and by adding this trend to the correlation becomes r=+0.983. The trend helps to explain why the effect of dust types, is related to its t-ratio forms.

2) Water:

Two types of water are used in Kuwait, namely fresh and brackish water. Fresh water is used for all domestic purposes, drinking, cooking, washing clothes, in the bathroom, washing cars, watering plants and for domestic animals, etc. Brackish water is used for irrigation of plantation, washing houses, courtyards, and sometimes washing cars. The usage of water in Kuwait has increased yearly, and there are regular pattern of water usage within the year, with increases during the summer months. **(Tables 6.14 & 6.15)**.

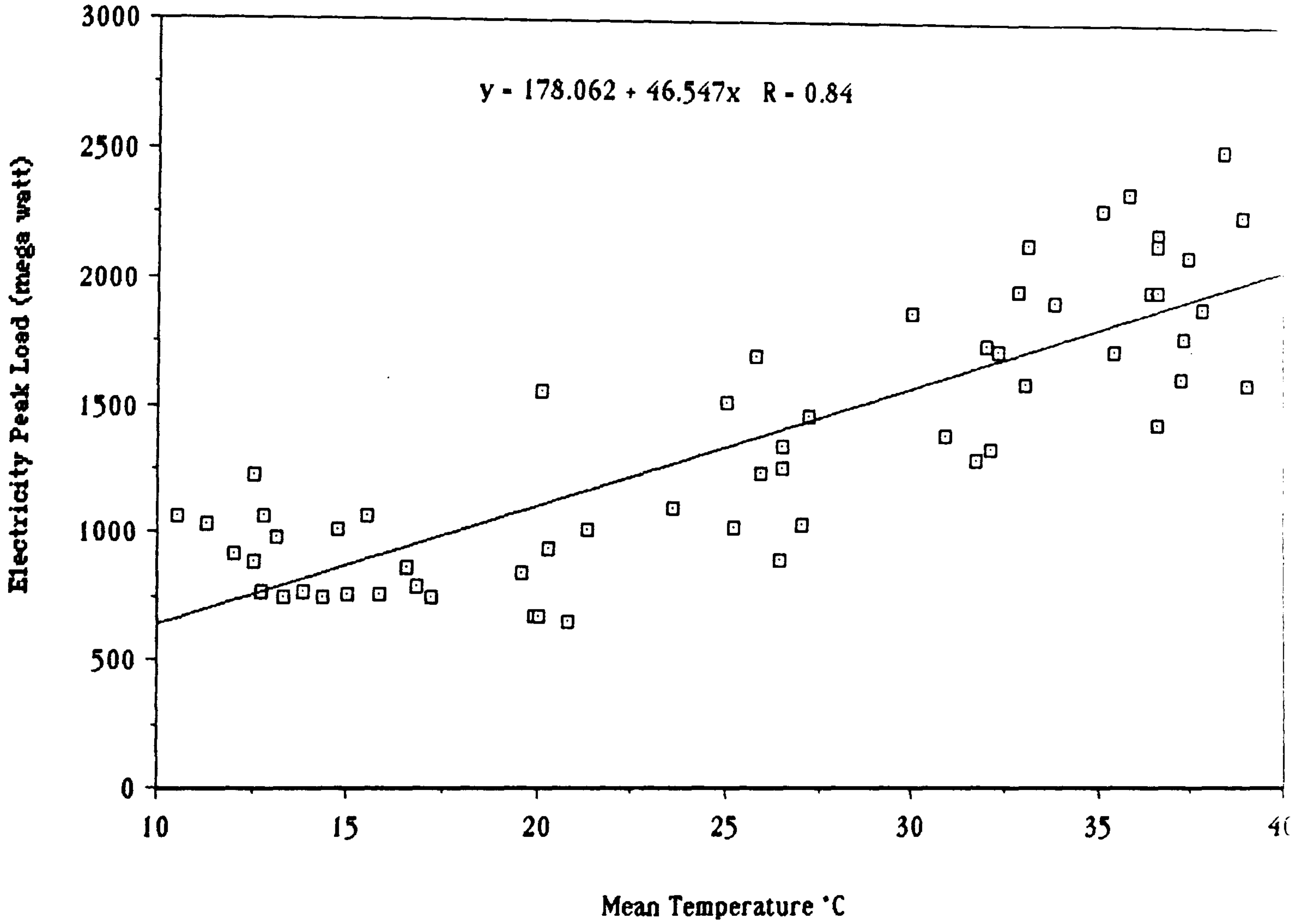


Figure 6-5: Correlation coefficient between the monthly average of electricity peak load (mega watt) and monthly mean temperature °C from 1980 to 1984 in Kuwait.

Month	1980	1981	1982	1983	1984
January	51.6	51.6	59.2	61.6	73.7
February	52.4	55.9	61.0	65.7	77.9
March	57.2	57.7	62.0	69.2	80.9
April	67.1	65.1	75.5	80.4	89.7
May	71.0	71.1	80.8	92.8	95.5
June	74.6	72.2	84.5	97.5	107.1
July	64.7	78.1	93.1	100.3	104.9
August	65.3	74.9	90.5	96.7	107.3
September	69.3	77.9	88.6	97.8	105.1
October	59.3	71.8	83.8	95.6	101.2
November	59.7	67.6	71.6	88.0	87.8
December	55.1	62.4	66.0	76.9	79.4

Table 6.14: Daily average consumption of fresh water by month in Kuwait 1980-1984 (in million Imp. gallons) (Imp. gallons=4.546 litres).

Month	1980	1981	1982	1983	1984
January	15493	15115	16336	21809	23939
February	13799	14880	17960	25487	26505
March	15934	21392	20606	29375	27788
April	22065	27637	29907	32004	38741
May	27629	33603	38227	41741	45797
June	32693	39130	45755	50422	54039
July	37265	41820	48211	53120	56055
August	38841	39948	50172	55128	50716
September	38114	37006	47824	50767	40687
October	32668	28196	36438	40838	34416
November	26393	23552	26803	31400	18677
December	18368	20382	23871	26241	18182

Table 6.15: Daily average consumption of brackish water by month in Kuwait 1980-1984 (in thousand Imp. gallons) (Imp. gallons=4.546 litres).

There are significant relationships between monthly average of water (both fresh and brackish) consumption and number of dust type days (n=60) **(Table 6.16, Figures 6.6, 6.7, 6.8, & 6.9)**

No. of Days	Fresh Water	Brackish Water
Dusty Days	+0.232	+0.502
Dust storm	+0.491	+0.564
Rising Dust	+0.369	+0.417
Suspended Dust	-0.045	+0.118
Haze	-0.155	+0.122

Table 6.16: The correlation coefficient between the monthly average of fresh water consumption (million Imp. gallons) and brackish water consumption (thousand Imp. gallons) and the number of dust type days in Kuwait 1980-1984 (n=60).

Generally, peak water consumption is not in June or July when the dusty days are most frequent, but in August and September when the dust storms frequency is decreased, and therefore it is easier to keep surfaces continuously clean. Besides cleaning houses from dust deposits, water is used to cool temperatures during hot summer days by sprinkling house court-yards and the front of houses. But the correlation coefficient between the monthly average of water (fresh and brackish) and temperature is stronger than with dust types, the correlation with fresh water being +0.554 **(Figure 6.10)** and +0.864 in case of brackish water **(Figure 6.11)** (n=60). In case of multiple regression between the monthly average of water consumption and the number of dust type days and temperature, the correlation value in case of brackish water (r=+0.918) is higher than fresh water (r=+0.709). The highest t-ratio in both cases (brackish and fresh water) is for temperature (12.01 and 4.73) followed by dust storm days (3.24 and 2.83). Thus dust storm days do have an effect on brackish water consumption, if not on that of fresh water.

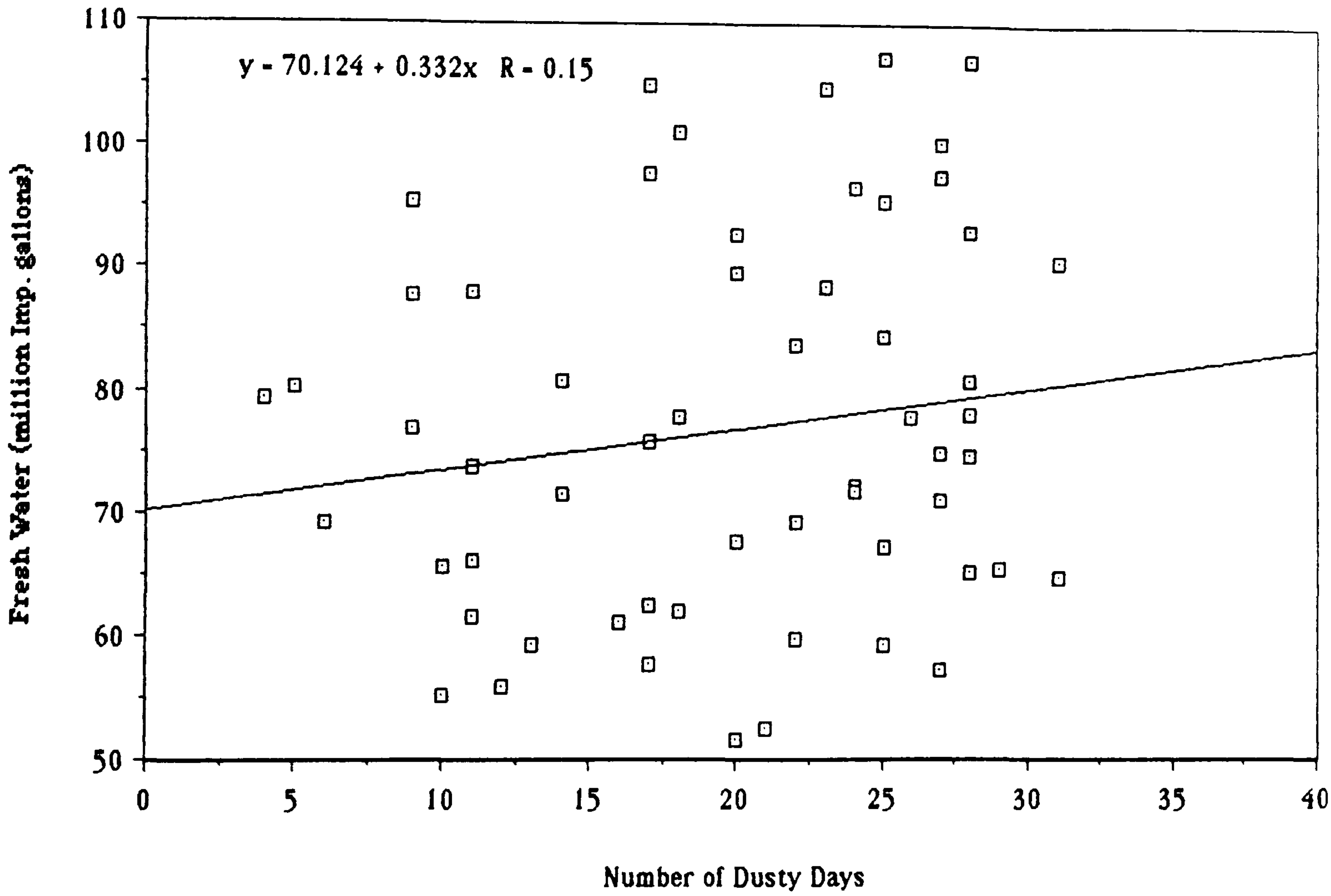


Figure 6-6: Correlation coefficient between the monthly fresh water (in million Imp. gallons) consumption and monthly total of number of dusty days from 1980 to 1984 in Kuwait.

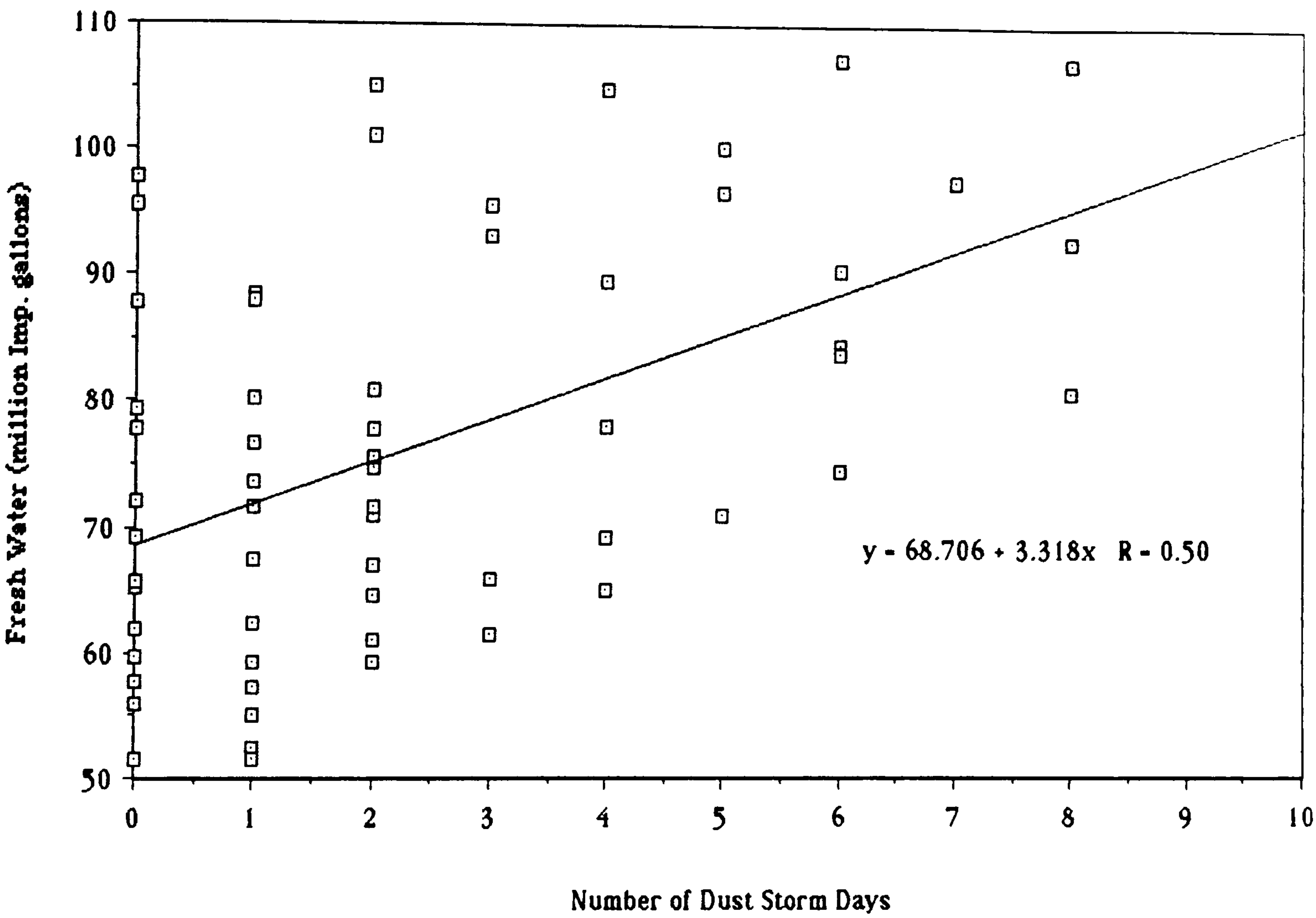


Figure 6-7: Correlation coefficient between the monthly fresh water (in million Imp. gallons) consumption and monthly total of number of dust storm days from 1980 to 1984 in Kuwait.

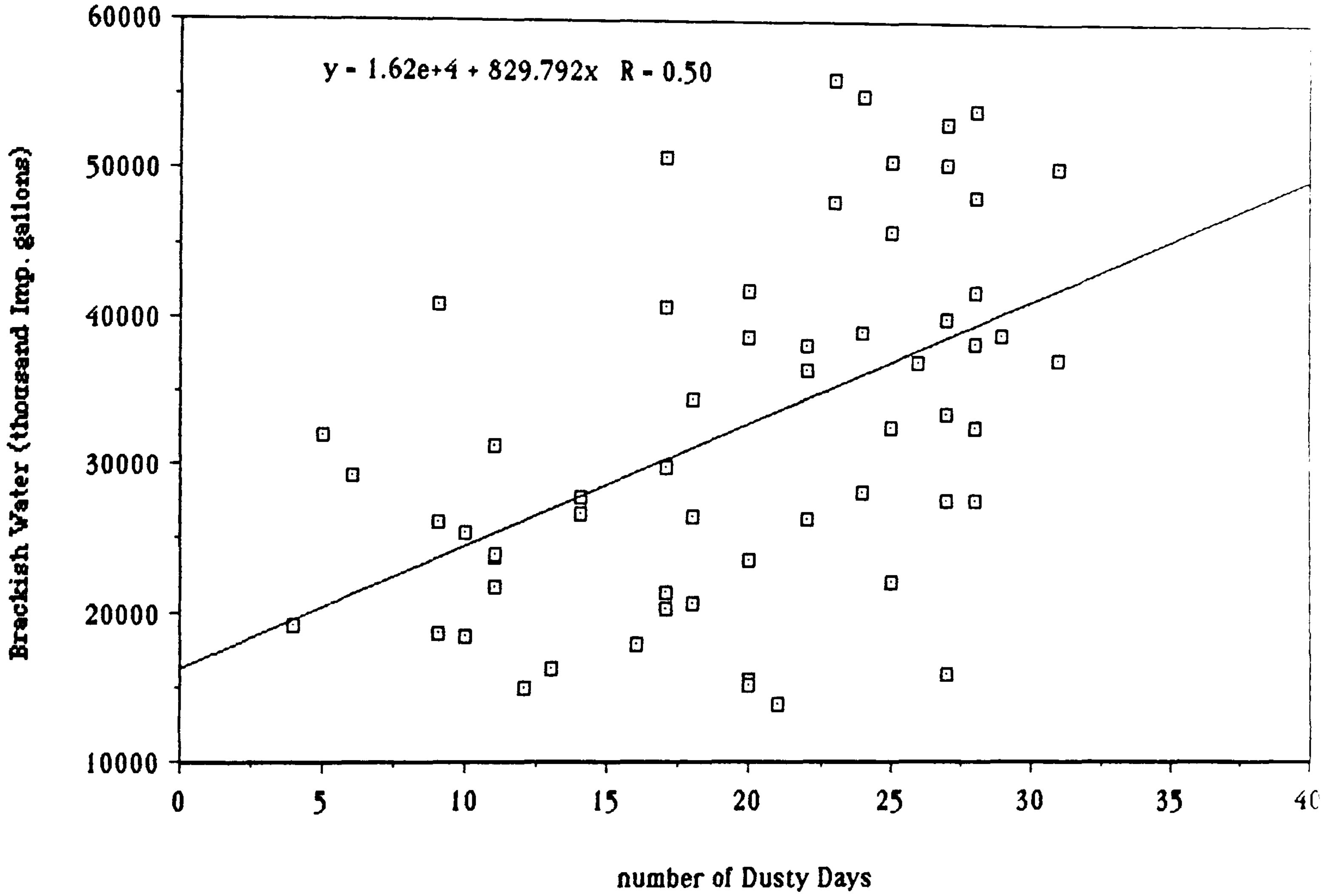


Figure 6-8: Correlation coefficient between the monthly brackish water (in thousand Imp. gallons) consumption and monthly total of number of dusty days from 1980 to 1984 in Kuwait.

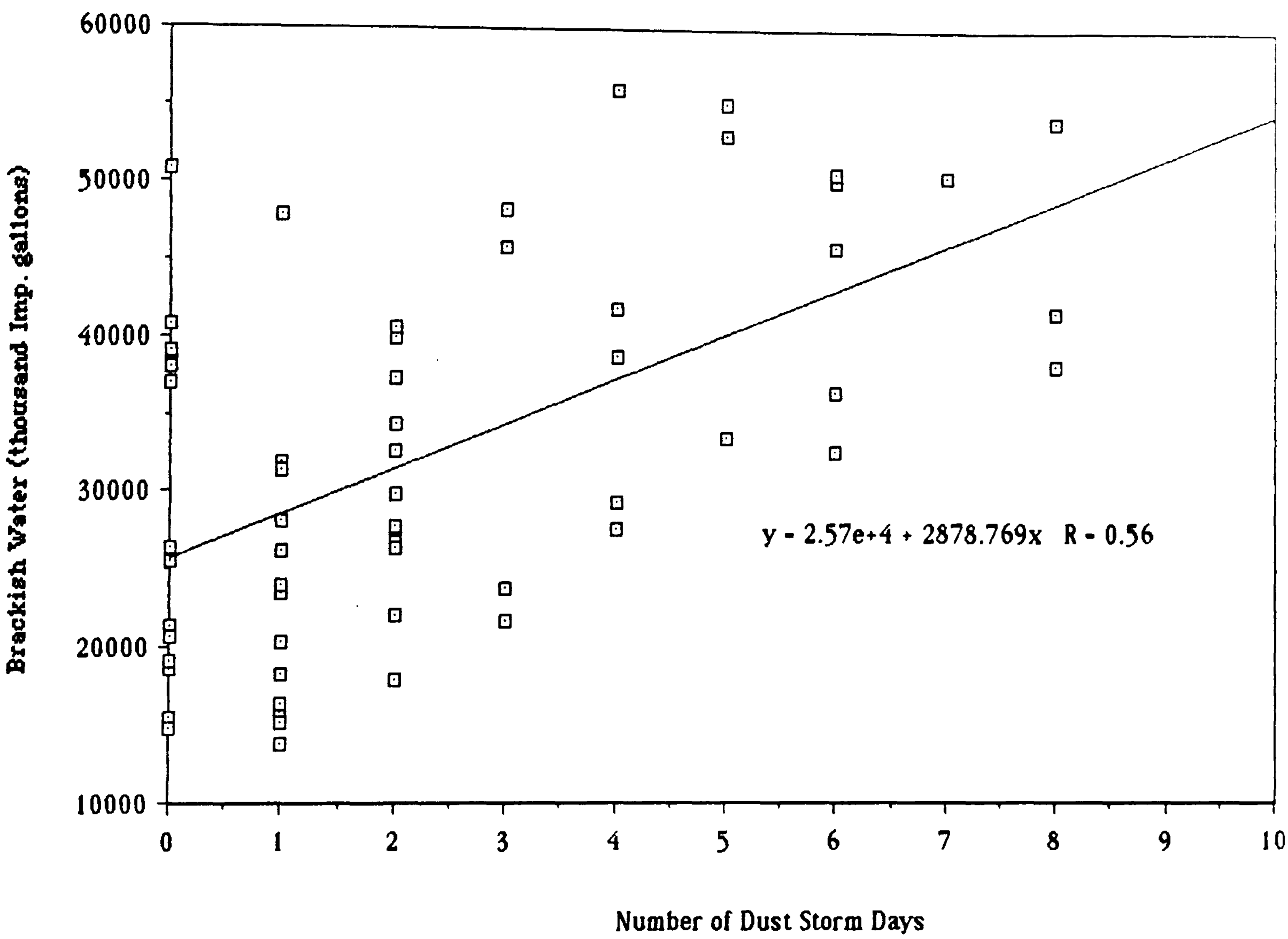


Figure 6-9: Correlation coefficient between the monthly brackish water (in thousand Imp. gallons) consumption and monthly total of number of dust storm days from 1980 to 1984 in Kuwait.

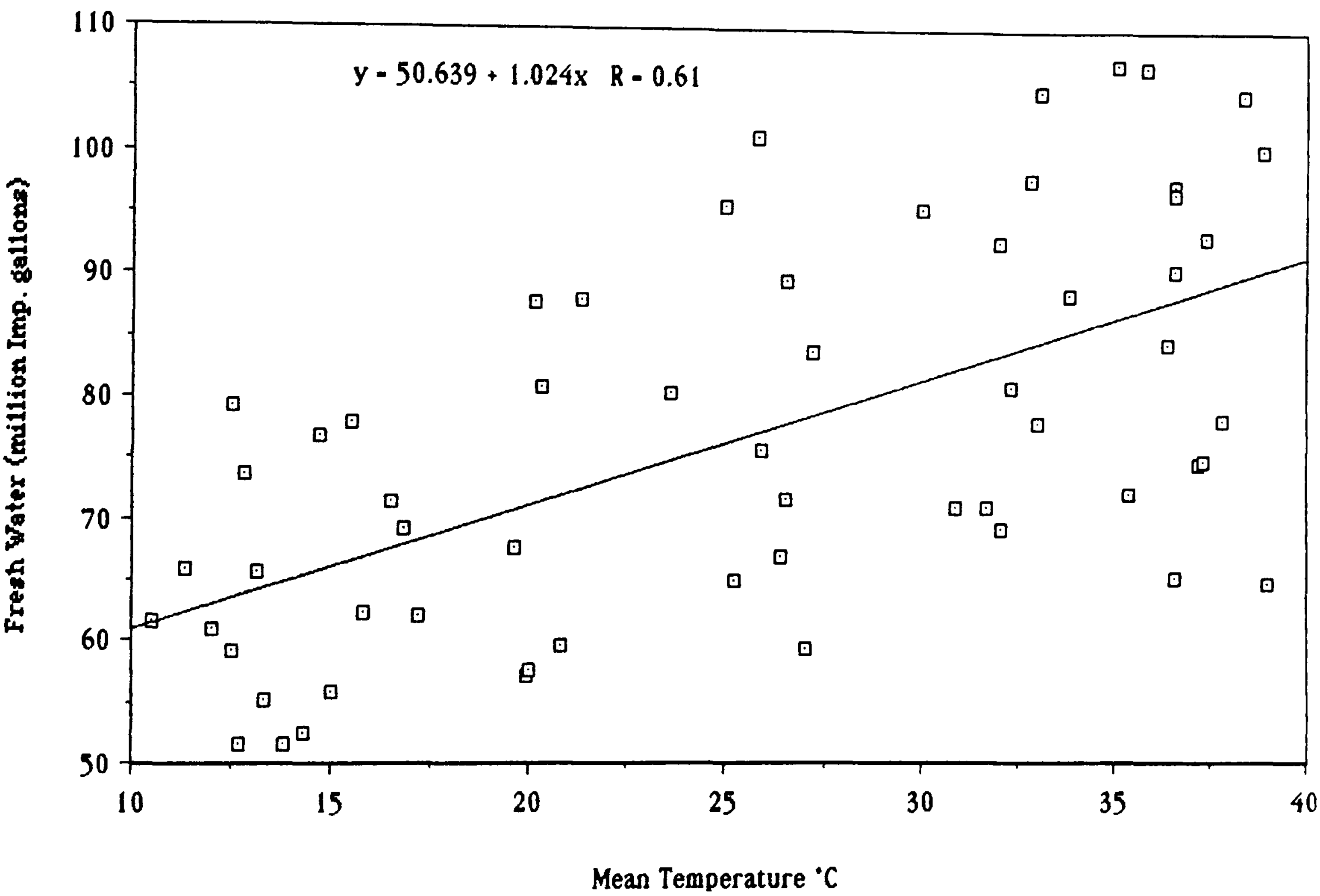


Figure 6-10: Correlation coefficient between the monthly fresh water (in million Imp. gallons) consumption and monthly mean of temperature °C from 1980 to 1984 in Kuwait.

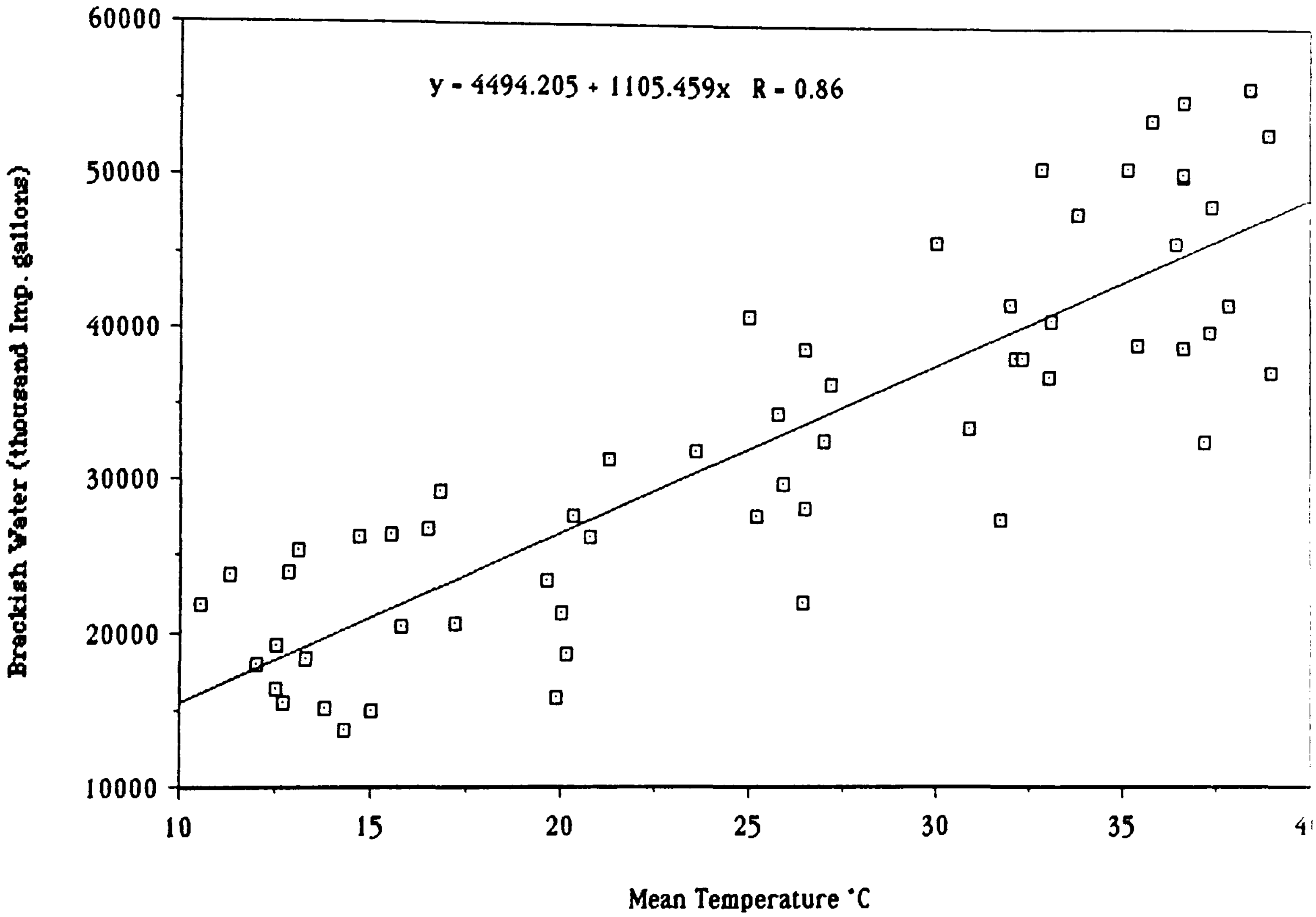


Figure 6-11: Correlation coefficient between the monthly brackish water (in thousand Imp. gallons) consumption and monthly mean of temperature °C from 1980 to 1984 in Kuwait.

CHAPTER SEVEN: DUST AND HEALTH

7.1) Introduction:

Dust storms are especially common in Kuwait during the summer. The increasing frequency of dust storm is a hazard for humans, because dust storms pick up fine loose materials. Some of these materials are organic and some are non-organic. The non-organic materials, include silicate minerals, such as clay from soils and volcanic dust, whilst organic materials include matter such as pollen, hair, bacteria and a great variety of fragments of plants and animals (Press, F. and Siever, R. 1986). These materials in dust storms play an importance role in causing allergic diseases. Some of these dust-related diseases merely cause mild discomfort to the patient, but other dust-related diseases may result in debility, degeneration and death (Leathers, Ch.R, 1981). Leathers, Ch.R. (ed. Péwé, p. 191, 1981) stated that

> "One of the most important dust-borne disease organisms in Arizona is Coccidioides immitis, the fungus that causes valley fever in man and certain animals. More than 27 human deaths each year have been caused by this organism in Arizona alone. Of 281 dust samples tested from the Phoenix area, 37 yielded the disease-producing fungus. The loss in personal income and the medical care costs each year due to valley fever in its endemic area are estimated conservatively at $320 million".

Valley fever may be caught in two ways; firstly by breathing in air contaminated by the fungus and which is transported by dust storms; secondly, by direct contact with contaminated soil, (the main groups at risk are farmers and people undergoing military field-training) (Levine, H., 1968). In the soil, Coccidioides immitis grows in a threadlike form called a hypha to form a mat or mycelium. While it is threadlike, tough structures called arthrospores are formed. During the dry weather, these threadlike structure fracture and the arthropores are released. They may become airborne. If they land elsewhere in the soil, they generate again a new hyphae, and the same process is repeated. On the other hand, if the arthrospores are inhaled and enter the lung, they become round-shaped and enlarge to many times their original volume. These enlarged arthro-spores are called spherules. They rupture and endospores are released. These become blood-borne and lymph-borne, and move to other loci in the body to generate new spherates (Levine, H. 1968).

Dust storms carry fungal and other infectious particles of other species which are found in the surface layer of soil. Some of these cause ringworm in both man and animals. Also, in some cases others cause mycetomas, localized cutaneous and subcutaneous infections. These infections mainly occur in the feet and hands following injury to the skin (Leathers, Ch. R., 1981).

In an American study between 1969 and 1973 , sixteen species of fungi were identified as disease vectors for both man and animals. These fungi were isolated from the surface dust of desert soils in Arizona (Leathers, Ch. R., 1981). Many types of fungi are found in the soils of the Riyadh region in Saudi Arabia. The count of fungi varies, with an increase during the wet season and decrease during the dry season (Abd El Rahman, A.A., 1986; Abu-Zinada, A.H. and El-Haseiny, T.M., 1975).

Some algae have been found in the desert soil of Saudi Arabia. Both the algae and blue-green algae increase during the period of rainfall in April to 10,000 organisms/gram dry soil (Abd. El Rahman, A.A., 1986; Abu Zinada, A.H. and El-Husseiny, T.M., 1975).

Pollen plays an important role in the allergic diseases, and is one of the components of dust storms. It enters the breathing system amongst fine dust particles and causes inflammation to the internal tissues of the chest. For instance, in Arizona, it was seen that the "yellow" dust including pollen from desert ragweeds (Ambrosia spp) blows during the spring. Another example is the blowing of golden plumes of powdery material from the mulberry trees (Morus alba) which line the streets in the southern parts of Arizona (Leathers, Ch.R., 1981).

A large quantity of pollen dust is freed into the air yearly. In Phoenix metropolitan area, in Arizona, there are more than 20,000 olive trees, which release more than 4 tons of pollen each year to become a part of the dust of the area (Leathers, Ch.R., 1981).

The size of airborne pollen is about 10 to 50μm or larger in diameter. This pollen is inhaled, triggering the symptoms of allergies in hay fever sufferers, including sneezing, watering and itching of the eyes, dripping nose and difficulty in breathing. About eleven million people in the United States suffer from hay fever and asthma annually (Leathers, Ch.R., 1981). "The Allergy Foundation of America noted that twenty five million man-days are lost annually to the U.S. workforce because of allergies to pollen, spores and other items" (Leathers, Ch. R. in Péwé 1981, pp. 195). Airborne dust pollen as a component of dust storms is a significant element in this problem.

7.2) Dust and Health in Kuwait:

Before the discovery of oil most of the population of Kuwait lived in

Kuwait City. They were dependent on the sea for their living, by fishing and pearl-diving (Al-Awadi, 1973; Al-Abdul Razak, 1974). During that period the dust hazard on people's health were unreported as a consequence of lack of health services in Kuwait. The first governmental hospital, Al-Amirie Hospital, was established in 1949. In contrast, nowadays, there are seventeen hospitals and sanatoria in Kuwait (Department of Public Health and Training, 1984). An allergy unit was established in 1966 in Subah Hospital (Al-Amadi, 1973), and recently specialist centres have been established, such as Kuwait Center for Allergic Diseases in 1984 (Kuwait Centre for Allergic Diseases, 1985; Department of Public Health and Training, 1984). As a result of the socio-economic changes which followed the discovery of oil, people become more widely distributed within the country. This socio-economic change saw a rise in the occurrence and reporting of some types of allergic disorder such as hay fever. For example, before the 1950's most of water was brought to Kuwait from Shut Al-Arab in Iraq (Al-Abdul Razak, 1974). In the early 1950's sea water desalination was developed in Kuwait to supply fresh water. With the greater availability of water, the government promoted a planting project over the country to control sand and dust movements. To achieve this aim, the government imported many types of trees which can survive the climate of Kuwait. These included Prosopis spicigera from Abadan, Iran, in 1951 (Al-Awadi, 1973; 1983; Wilkinson, 1964), Tamarix spp., Eucalyptus spp., Albizzie spp., Acacia Salicina (Sheeha, 1984; Al-Awadi, 1973; 1984; Wilkinson, 1964). Furthermore grasses were introduced to Kuwait such as Bermuda grass (Cynodon dactylon) and two Chenopodiaceas members, Galsola spp. and Cornulaca spp. (Al-Awadi, 1973; 1983, Wilkinson, 1969).

As a result of the plantation project and the importation of trees and grasses from outside the country, there was an increase in complaints and reports of allergic disorders. In 1954, in Ahmadi city many cases of allergies have been attributed by Dr.Wilkinson as being related to plantations (Wilkinson, 1969; Al-Awadi, 1973).

Many factors play a significant role in allergies and other dust related diseases. These include pollen of weeds and grasses, dust storms, cool air conditioning, and the home dust mite (Al-Awadi, 1973; 1983; Mohamed, Abdul Haii and Al-Kazmy, 1983; Wilkinson, 1964). These are examined individually.

1) Pollen grains and fungi in the air: By increasing the area of plantation in Kuwait, in public gardens, schools and streets, as the result of increased availability of water, the amount of pollen grains (especially the Prosopis pollen) has also increased in the air. This type of tree is thought to be one of the main causes of allergy in Kuwait (Al-Awadi, 1973; 1983; Wilkinson, 1964). Correlation analysis between the density of Prosopis trees in various locations in Kuwait and the prevalence of allergy was carried out. The correlation was strong and positive for Prosopis ($r=+0.712$) (Al-Awadi, 1973; 1983). Furthermore the correlation made between the density of each type of trees in the locality and the prevalence of allergy in each residential areas was positive **(Table 7.1)**

Trees	r	Trees	r
Prosopis sp.	0.712	Jasminum sp.	0.194
Thevetia pherifolia	0.423	Parkinsonia sp.	0.187
Tamarix sp.	0.393	Washingtonia sp.	0.121
Lawsonia sp.	0.379	Nerium odorum	0.097
Zizyphus vulgaris	0.343	Vitex ajuncasts	0.095
Eucalyptus sp.	0.337	Alibizzia sp.	0.044
Phoenix canariensis	0.334		

Table 7.1: The correlation coefficient between the density of the major types of trees and the prevalence of allergy in the locality of Kuwait (After: Al-Awadi (A)., p. 19, 1973).

Therefore the most important role in causing allergy in Kuwait by pollen, is that of the Prosopis tree (Al-Awadi, 1973; 1983; Mohamed, Abdull Haii and Al-Kazmy, 1983; Wilkinson, 1964). The average concentration of pollen grains of Prosopis trees in the air over the year was 9,370 pollen/cm^3/day, reaching a the maximum in March (67,550 pollen/cm^3/day) (Al-Awadi, 1973). An example of the scale of planting can be seen in Ahmadi City, 25 miles (40 km), south of Kuwait, where about 30,000 specimens have been planted **(Table 7.2)**.

Tree Name	Number of Trees
Prosopis sp.	10,000
Tamarisk sp.	10,000
Eucalyptus sp.	6,000
Parkinsonia sp.	2,500
Albizzia sp.	1,500
Acacia sp.	500
Casuarina sp.	200

Table 7.2: Number of trees and shrubs planted in Ahmadi City over an area of about two and a half square miles (After: Wilkinson, pp. 17, 1964).

In 1954, the majority of patients who complained of severe rhinitis, conjunctivitis, bronchospasm and generalized urticaria, were people who had lived in Ahmadi from its inception. Complaints are concentrated between in April and September. People in Bahrain and Dhahran, Saudi Arabia, also complained of hay fever produced by Prosopis pollen grains (Wilkinson, 1964).

In the case of fungi in 1970, the concentration of fungal spores in the air in the Kuwait was counted. The monthly mean of spores in the air over the whole country was 54 fungi/m^3/day, reaching a maximum count in March and a minimum in November. The main fungi types were Asperigellus spp. (23.7%) and Alternaria spp. (23.7%) (Al-Awadi, 1973). All of these pollen grains and spores counts are transported by wind amongst dust particles.

2) Dust Storm: Dust storms are recognized as one of the most significant harmful agents to human health in arid and semi-arid regions. The eye disease, Pterygium, is described by the Butterworths Medical

Dictionary (pp. 1406, 1980):

> "A degenerative condition in which a triangular area of fleshy conjunctiva extends on to the cornea, with the apex towards the pupil, usually situated on the nasal side. It is common in windy dusty climates".

Dust particles can enter the human body by inhalation or through the eyes, mouth, ear or skin. Many people complain of resultant allergies in Kuwait do so during the summer months. The highest number of complaints is reported in June followed by July, August and April (Al-Awadi, 1973). A study carried out by Dr. Al Awadi (1973) pointed out that there are a significant and positive correlation between the monthly mean of dust fall and the seasonal exacerbation of allergy symptoms (r=+0.762).

Correlation coefficients were calculated between dust components and exacerbation of allergy **(Table 7.3)**.

Dust Components	r
Soluble fraction	+ 0.289
Combustible matter	+ 0.616
Tarry mater	+ 0.316
Ash	+ 0.777
Total dust	+ 0.762

Table 7.3 : Correlation coefficient (r) between the dust components and the seasonal exacerbation of the symptoms of allergy in Kuwait (After Al-Awadi, pp.34,1973).

Correlation coefficients have been calculated between the monthly values of type of dust, temperature, wind speed, relative humidity and soluble and insoluble fractions of dust-fall and with allergy types, chest, nasal and skin allergy, for 1985. The results were insignificant except for soluble fraction of dust-fall, particularly with sulphate and chloride components **(Table 7.4)**.

	Nitrate	Sulphate	Chloride	Other soluble	Total soluble
Chest Allergy	+0.170	+0.674	+.557	+0.352	+0.506
Nasal Allergy	+0.1	+0.771	+0.519	+0.387	+0.541
Skin Allergy	+0.434	-0.190	-0.130	-0.187	-0.134

Table 7.4: Correlation coefficient between monthly soluble fractions of dust-fall (ton/km^2) and number of new cases of allergy types in Kuwait in 1985.
(Significance level 0.1=0.549 for d.f.=12).
(Kuwait Center for Allergy Diseases, 1985; Kuwait Protection Coucil, 1985)

Table 7.4 shows that the effect of the soluble fraction of dust-fall was insignificant as a factor in causation of skin allergies. In contrast, there was a significant effect of the soluble fraction on chest and nasal allergies, especially the sulphate and chloride fractions. These two components are more common in the two main industrial areas of Kuwait including the Shuaiba industrial area in the southern part of Kuwait which is close to Fahahed, Ahmadi. This area is one of the main petro-chemical industrial zones, producing chemical fertilizers such as urea and ammonium sulphate. The second main industrial area in Kuwait is Shuwaikh, which is located in Kuwait city. It mainly produces chlorine, detergents, and hydrochloric acid. These two industrial areas affect the neighboring localities **(Table 7.5)**.

Locations	Nitrate	Sulphate	Chloride
Kuwait City	0.34	1.83	1.39
Shamiya	0.31	1.4	1.36
Sulaibikhat	0.43	1.57	0.97
Mutlla	0.38	1.241	1.04
Farwaniya	0.46	1.16	1.03
Salmiya	0.39	1.37	1.1
Shuwaikh	1.12	1.5	1.45
Shaiba	0.55	2.66	1.5
Fahaheil	0.42	1.9	1.35

Table 7.5 : The monthly mean of weight of soluble fraction of dust-fall components over various locations of Kuwait 1983-1985 (tons/km^2). (Kuwait Protection Council, 1983; 1984; 1985)

It is clear that dust plays an important role in increasing chest and nasal allergies. According to the Allergy Unit in Sabah Hospital, Kuwait City, most of the allergy cases in 1982 complained that the dust storms, more than heat, cold or humidity affected these illnesses **(Table 7.6)**.

	Nose	Chest	Chest & Nose	Other	Total
Heat	17	13	18	2	50
Cold	2	6	2	2	12
Humidity	36	43	45	3	127
Dust Storm	59	54	61	5	179

Table 7.6: The distribution of allergy cases according to triggering environmental factors reported to the Allergy Unit, Sabah Hospital, Kuwait, 1982. (After: Mohamed; Abdull Haii & Al-Kazmy, Table 5, 1982).

The role of dust storm in causing allergies amongst the respondents revealed insignificant differences between the four governorates (Capital, Hawalli, Ahmadi and Jahra) (d. f.=3, chi^2=3), between Kuwaiti and non-Kuwaiti nationals (d.f.=1, chi^2=0) and between age groups (d.f.=2, chi^2=0.34). In contrast, there were significant differences in the role of dust as a cause of allergy by gender in Kuwait, (d.f.=1, chi^2=5.43) **(Table 7.7)**.

	Male	Female
Reported dust allergy	77	78
Did not report	130	80

Table 7.7: Number of respondents by gender reporting a dust allergy.

In total 42.5% of respondents had allergies related to dust storms while 57.5% did not. The highest complaint of respondents were low nose allergy (35.1%) followed by asthma (29.1%), sneezing (9.9%) and eyes and nose allergy (7.9%) **(Table 7.8)**.

Allergy	Male	Female	Total
Nose	29	24	53
Asthma	22	22	44
Sneezing	7	8	15
Eyes and Nose	7	5	12
Eyes	5	6	11
Nose and Throat	1	9	10
Skin	2	2	4
Throat	1	-	1
Headache	-	1	1

Table 7.8: Distribution of type of allergies reported by gender in Kuwait.

Apart from the occurrence of dust storms, wind direction has an important role in the seasonal exacerbation of allergy in Kuwait. There are positive correlation coefficients between the northern and north-westerly winds and exacerbation of allergy (NNW=+0.679, NW=+0.454 and N=+0.399) (Al-Awadi, 1973). In contrast, there were negative correlations between the south-easterly winds section and the exacerbation of allergy (S=-0.701, SSE=-0.660 and SEE=-0.479) (Al-Awadi, 1973).

Wind speed is a further important factor in exacerbation of the symptoms of allergy in Kuwait. A correlation coefficient of r=+0.684 has been found between the monthly mean of wind and the exacerbation of the symptoms of allergies revealed (Al-Awadi, 1973).

3) Air-conditioning: Use of air conditioning for cooling in Kuwait during summer is common, when daytime temperatures may reach 42°C. This can cause a peak difference of about 40°F (22°C) between the internal and external temperatures of building (Wilkinson, 1964). The cold air from air conditioning systems commonly causes vasomotor rhinitis in susceptible subjects, while constant draughts which result from air conditioning disseminate dust, sand and pollen throughout houses (Wilkinson, 1969). By 1973 there were 138,457 cooling air-conditioning units in Kuwait which are in frequent use between the end of March to early October (Al-Awadi, 1973).

The correlation coefficient being the number of cooling air-condition units per 100 persons living in the locality and the prevalence of allergy in each locality was highly positive (r=+0.782) (Al-Awadi, 1973; 1983).

Air-cooling is probably an aggravating factor in allergic subjects and is responsible for the exacerbation of their symptoms, especially when exposed to it overnight (Wilkinson, 1964).

4) House-dust Mites: These are one of the major causes of allergic rhinitis and asthma (Miyamoto, Oshima, Ishizaki and Sota, 1968; Wharton, 1970; Sinha, Bronswijk and Wallace, 1970; Voorhorst, Spieksma, Verekamp, Leupen and Lyklema, 1967). In the United States, such condition from one third of all chronic allergies of children under 17 years old.

The house-dust mites have been described by Fair, A., (Bronswijk & Sinha,pp.31, 1970) as:

> "Small mites (adults 170-500μ); cuticle finely or coarsely wrinkled; tarsi ending in a globular pulvillus and a small claw; anus ventral; vestigial genital sense organs present in both sexes; vulva of the females reverse Y or V-shaped; oil glands present and open between L2 and L3; vertical setas absent."

Mites, especially Dermatophagoides pteronyssinus and Dermatophagoides farinae, are considered to be the major allergenic constituent of house dust (Mohamed, Abdul Haii and Alkazmy, 1983; Wharton, 1970; Sinha, Bronswijk and Wallace, 1970; Voorhorst, Spieksma, Varekamp, Leupen and Lyklema, 1967).

5) Inhaled Dust Particles: Suspended particles have an important role in affecting people's health, because these particles are so small in size that they can enter the human body by inhalation. Particularly important are those particles which are less than 7 microns in size (Environment Protection Council, (A), 1984; (B), 1984). Particles with a size range lies between 3-7 microns are in the main trapped in the respiratory passages and therefore do not reach the lungs. But, particles in the size range of 1 to 3 microns are more dangerous, because they are deposited on lung tissue. Suspended particles which are less than one micron are moved immediately out of the body by expiration (Environment Protection Council, (A), 1984; (B), 1984). Air samples were collected in Kuwait from three locations in 1984; Kuwait City, Shamieh and Shawaikh. Of the total content of suspended particles in the air, it was found that Kuwait city air contained 61.5%, Shamieh 62.9% and Shuwaikh 63.3% of suspended particles, less than seven microns in diameter.(Environment Protection Council, (A), 1984; (B), 1984) **(Table 7-9)**.

Size Range Particle (micron)	Kuwait City	% in Size Range Shamieh	Shuwaikh
0.0-1.1	32.7	33.6	30.6
1.1-2.0	5.7	4.8	5.5
2.0-3.3	9.7	8.9	9.73
3-7.0	15.2	14.2	17.1
7.0 +	36.7	38.5	37.1

Table 7.9: Size distribution of suspended particles matter in various districts of Kuwait during 1984.
(After: Environment Protection Council, pp. 13, (A), 1984).

7.3) Dust and Allergy Types in Kuwait:

The number of allergic patients in Kuwait is increasing. Allergic patients between 1983 to 1985 increased by 15.5%. In 1985 50.4% of outpatient visitors to Kuwait Allergy Centre complained of asthma, 42.5% of nasal allergies and 7.1% of skin allergies. According to the survey, the majority of respondents (35.1%) complained of nasal allergy, 29.2% of asthma, 9.9% of sneezing, 7.9% of both eye and nasal allergies and 7.3% of eye allergies. The lowest number of respondents complained of throat

(0.7%), headache (0.7%) and skin allergies (2.6%) **(Table 7.10)**.

Allergy Type	Capital	Hawalli	Ahmah	Jahra
Nasal	49	32.9	40	32
Asthma	53.3	27.6	25.7	24
Sneezing	0	11.8	11.4	8
Eyes & Nasal	0	9.2	11.4	4
Eyes	6.7	9.2	2.9	8
Nasal & Throat	0	3.9	5.7	2.0
Skin	0	2.6	2.9	4
Throat	0	1.4	0	0
Headache	0	1.4	0	0
	100%	100%	100%	100%

Table 7.10: Percentage of respondents complaining of allergies by governorates.

Capital and Ahmadi governorates have higher numbers of nasal allergic patients than Hawalli and Jahra. As has been discussed, this is related to the organic matter of dust which comes from the industrial areas in these two governorates.

In Capital governorates the percentage of respondents who have asthma is high, due to Prosopis pollens. The Prosopis tree was planted during the 1950's in large number in Kuwait City (Al-Awadi, 1973). 94.5% of respondents believed their allergy was caused by air and as against only 5.5% of respondents who believed the cause was hereditary.

A total of 24.8% of respondents reported an illness which is enhanced by the dust storms. Most of them are from Ahmadi governorate (29.8%) and there were more females (29.6%) than males (21.4%). Furthermore

38% of respondents have a member of the family with an illness which is enhanced by dust storms. Typically dust storms cause difficulty in the breathing and 71.7% of respondents who reported some difficulty in breathing caused by dust without necessarily causing illness or allergy **(Table 7.11)**.

Response	Capital	Hawalli	Ahmadi	Jahra
Yes	39.5	36.5	40.0	38.1
Sometimes	31.6	33.9	31.4	38.1

Table 7.11: Percentage of the respondents who have difficulties in breathing during the dust storms by governorates.

7.4) Dust and Time Scale of Effects:

Dust particles have been shown to have significant effects on various parts of the human body such as the eyes, nose, chest. These effects could be divided into two time scale: short and long term effects. The short term effect includes those effects which become noticeable very quickly. A typical example can be seen in dust effects on the eyes, such as redness in the eyes caused by hot, dry and dusty air. This redness is accompanied by itching and production of tears (pers. comm. 1986). Such effects are immediate. Long term exposure to dust causes many types of diseases, including silicosis, and climate droplet keratitis. Silicosis is caused by the inhalation of dust containing free silica (Givlini, 1983; Becker, Butterfield, Harvey, Heptinstall, Thomas and Manuila, 1986). The climate droplet keratitis is an eye disease in which dust particles play a significant causal role (Newell, 1982). It was first reported in the Red Sea region and the Arabian Gulf in the 1930s. In reports it is most prevalent in Western Asia, Arabia and Australia in the 1970s (Rodger, 1981).

The basic cause of allergy is the human body's reaction to the entry of an allergen (antigen) such as dust particles, hair of cats or dogs, face powder, or pollen by inhalation (Havard, 1987; David, 1981). When these antigens enter the body the antigen starts to react, resulting a union of antibody with antigen, causing histamines to be liberated. Histamine in turn induces local vasodilatation and oedema with consequent wheal and erythema formation (David, 1981; Havard, 1987).

In summary, the main effect of dust in Kuwait, was found to be on the nose and followed by the eyes **(Table 7.12)**.

Body's Part	Total Score	% of Total to Max.
Nose	1173	67.6
Eyes	1104	63.4
Chest and breathing	997	59.5
Throat	905	56.2
Face	897	53.6
Ears	764	46.4
Skin	742	46.1

Table 7.12: The total score and percentage of total to the maximum score of number of respondents who claimed that their body's parts were affected by dust.

Additional investigation was made of significant differences of dust effects on parts of the body by using the chi-square test. The significance level used was 0.1.

1) Over the four governorates of Kuwait there was no significant differences by dust effect on the body's parts; except in case of nose and

skin allergies. Nasal allergies have more significant differences than skin allergies, as chi^2-20.71 and chi^2-11.30 for d.f.-6. That is because the nose has a direct contact with the dust contaminated air, and it is the main entrance of dust and fine particles to the body. But in case of skin allergies these are as a result of specific allergy. This does not mean that dust storms have no differential effects on the parts of the body between the four governorates **(Apendix II)**, but because the parts which people can easily notice which related to dust are nasal allergies and skin. Also nasal allergies are related to breathing difficulties. The majority of respondents reported that they suffer from nose allergy closely followed by asthma **(Table 7.13)**.

Allergy Type	Capital	Hawalli	Ahmadi	Jahra
Nose	40.0	32.9	40.0	32.0
Asthma	53.3	27.6	25.7	24.0
Sneezing	0.0	11.8	11.4	8.0
Eyes and nose	0.0	9.2	11.4	4.0
Eyes	6.7	9.2	2.9	8.0
Nose and throat	0.0	3.9	5.7	20.0
Skin	0.0	2.6	2.9	4.0
Throat	0.0	1.4	0.0	0.0
Head ache	0.0	1.4	0.0	0.0

Table 7.13: Percentage of respondents by governorates according to type of allergy which they are suffering from.

Capital governorate seems to have a pattern of allergies more related to the respiratory system. It may be related to the fine dust particles which come from the marshes which lie around Kuwait Bay in the north west of

Capital governorate. Secondly, it may be related to the Prosopis pollen grains of early plantation schemes in Kuwait city. These have the same effect in the Ahmadi.

2) It been found that there is a significant difference in of dust related allergy between Kuwaitis and non-Kuwaitis particularly relating to the throat and chest or breathing categories. The result was chi^2-8.71 for throat and chi^2-5.77 for chest with 2 degree of freedom. This may be because they are not familiar with and could not cope well with the type of weather in Kuwait. They are more likely sensitive to dust storms than Kuwaitis because severe dust storm do not occur in their countries.

PART THREE

CHAPTER EIGHT: DUST PROBLEMS: MANAGEMENT AND RECOMMENDATIONS

8.1) Introduction:

Management in this context, can be regarded as a positive reactions of man to environmental hazards to reduce the degree of hazard. Environmental hazards may be as a result of human activities such as industrial development, and examples of such hazards include air and water pollution (Moran, Morgan and Wiersma, 1980). Alternatively the hazard may be due to a natural event, such as a flood, earthquake, or the problem may be a result of interaction between human and natural actions, such as desertification caused by destroying or removing the vegetation as a result of overgrazing, or firewood collection, thereby increasing wind erosion (McTainsh, 1985). Similarly increasing the flow of run-off may increase the flood threat (Moran, Morgan and Wiersma, 1980). Environmental hazards cause much damage to the communities in respect of both lives and money. For instance, in the flood of 1975 the Federal Insurance Administration estimated the annual loss in the United States to be 3.8 billion dollars (Moran, Morgan and Wiersma, 1980). There were more than 130 lives lost in the Big Thompson Canyon in Colorado (U.S.A.) in 1976 when heavy rain caused the water level to rise unexpectedly (Moran, Morgan and Wiersma, 1980). In December 1977, a great deal of damage was done by a severe sand storm in San Joaquin Valley, California. Many houses and buildings had windows and roofs damaged, and many barns and aeroplane hangers were blown down

(Wilshir, Nakata and Hallet, 1981). In the meantime, immature crops such as potatoes, onions and carrots were extensively damaged by sand blasting and by root exposure. Young citrus trees were destroyed by sand blasting (Wilshir, Nakata and Hallet, 1981).

There are many example of cultivated lands and farms being covered by sand movements. For instance, in China, at Winlidun, an oasis village south of the Great Wall, Lin Jiancheng, a local farmer has moved four times. Each move was directly related to the sand movement over his farm. The first two times were before 1949, the third one in 1962 and the last time was in 1980 (Yongyao, 1987). The same phenomenon has long existed in the eastern part of Saudi Arabia. The sand cover has moved to many farms and villages (Al-Abdull Wahed, 1982).

There are reports for countries in the Middle East of sand drifting over cultivated lands and villages, including Saudi Arabia (Al-Abdull Wahed, 1982), Iraq (Gati, 1989), Iran (Tavakoli, 1982), Southern Yeman (Ba-Zurah, 1984), Kuwait (Shakatrhh, 1986; Al-Shapee, 1984).

Dust and sand storms are one of the results of soil degradation. In many examples of desertification over the world the main concern is with sand dune mobilisation (McTainsh, 1985; Tavakoli, 1982; Yongyao, 1987). But, the finer fractions of the sands, silts and clays which mobilise as dust storms have received much less attention (McTainsh, 1985). Like sand drift, dust storms are one of the signs of desertification, because they are mainly caused by destruction of vegetation cover (Zhunda and Shu, 1981; McTainsh, 1985). Desertification is the main environmental degeneration which takes place in arid and semi-arid regions of the world (Zhunda and Shu, 1981). Therefore, dust mobilisation is perhaps the most important effect of soil erosion caused by wind (McTainsh, 1985).

It has been noticed within the Sahel-savanna area of northern Nigeria, that during the wet season a lush grass cover conceals any appearance of soil degradation (McTainsh, 1985). Sand dune movement has an important effect on the entrainment and loss of the dust component. As dust may be a major part of sand dunes, its presence significantly increases the structural stability, soil moisture storage capacity and chemical fertility of dunes. Hence, removal of the dust component during the drought period is an important part of the degradational process (McTainsh, 1985). Dust mobilisation rates can be used as an index of the stability of soil. These rates are controlled largely by vegetation cover and both are critical manifestations of desertification (McTainsh, 1985).

The management process starts from understanding the problem. There are three main factors which play a significant role in dust storm occurrence. They are (McTainsh, 1985; Gati, 1984; Tavakdi, 1982) :

1) strong wind speed and direction;

2) weak sand coherence (dusty, sandy and dry soil) which is due to the absence of vegetation cover;

3) Human activities which have a negative environmental effect such as overgrazing, burning collecting of firewood, or abuse of cultivated land in arid and semi-arid regions or over-use of irrigation water which leads to the increase of soil salinity.

So, management recommendations are considered which are based on these three factors to reduce the hazard of environmental impacts. Further it must be borne in mind that most of the literature discusses sand mobility rather than that of dust. That is because of the physical impacts of sand drifts appear more quickly than those of dust; secondly, dust movements are included within the sand movement due to dust particle sizes. This means that dust and sand control programmes need a long time in order to reach their goals. For instance, programmes were begun in Saudi Arabia in 1961 (Al-Abdull Wahed, 1982), Iran, in 1958 (Tarakoli, 1982) and China. Such programmes takes at least ten years or more to show results (Yongyao, 1987) and in all cases there is much yet to be achieved.

8.2) Dust and Sand Control Programme:

One of the most significant factors in the occurrence of dust and sand storms is the absence of vegetation cover (Kassas, 1987; McTainsh, 1985; Ondeng'e, 1984). There have been many successful dust control programmes over the world. These programmes are largely concerned with the control of dust and sand sources, typically sand dunes. These programmes start with replanting these source locations with suitable plants.

An experiment was carried out by the Lanzhon Institute of Desert Research in China. The programme set out to control shifting sand which was mobilizing in the northern and north-western part of China (Yongyao, 1987; Zhanda and Shu, 1981; Ondeng'e, 1984; Xingliang, 1979). The area which suffered from desertification was about 170,000 square kilometres and affected about 207 counties of Northern China with a total population of 35 million people (Zhanda and Shu, 1981; Ondenge'e, 1984).

Areas which were affected by desertification were divided into three categories according to their origin and geographical distribution (Zhanda and Shu, 1981):

1) Desertified lands in arid steppe and desert steppe regions, where human activities have affected these lands by over-utilization for agriculture, animal husbandry and firewood collection.

2) Desertified lands in, or near, oases and in the lower reaches of rivers

in arid desert regions, which result in changes of river courses and in exhaustion of water resources.

3) Desertified lands in semi-humid zones which have sandy soils and strong dry-season winds. The soil is characterized by alluvial sand layers derived from rivers or sandy deposits laid down by floods.

In general, in these zones the plant cover has been destroyed by human activities and thus leads to wind erosion and desertification **(Table 8.1)**.

Causes of Desertification	Per Cent
1) Destruction of Vegetation by firewood collection	32.4
2) Over-grazing	29.4
3) Cultivation of marginal lands	23.3
4) Irrational utilization of water resources	8.6
5) Advance and encroachment of sand dunes	5.5
6) Destruction of vegetation when building factories, mines, communication lines and cities	0.8
	100%

Table 8.1: Types of recent desertified lands in North China (after Zhanda and Shu, 1981, pp. 15).

Generally, the results of the Chinese experiment can be summarised as follows:

1) Planting of wild plant species as a wind breaks such as Tamarix spp., Nitraria spp., Glycyrrhiza spp., Sophora alopecuroides, Alhagi sparsifolia (Xingliang, 1979). By the third to fifth years of planting, wind velocity has been slowed down by 40-50% (at one metre above the ground) (Xingliang, 1979).

2) Strict prohibition of grazing flocks, collection of firewood, and cutting of grass, especially in the first years. When natural vegetation cover reachs 60-70%, controlled grazing may be allowed (Xingliang, 1979).

3) Protection and management of the planted area (either by local communes or forestry centres) and of pasture land. For example, in Wulidun village the district government patrolled the area with workers on motorcycles to prevent damage from irresponsible livestock grazing (Youngyao, 1987).

By this project China is proceeding to build a "great wall of green" in the north (Xingliang, 1979; Chen,pp.24, 1987).

The second example considered is an Iranian experiment. This experiment deals mostly with the Salt Desert. As discussed in chapter four, there are two large deserts in Iran. The northern one is Dasht-e-Kavir and the other is Dasht-e- Lut (Cressey, 1963; Fisher, 1950; Kardavni, 1980; Tavakoh, 1982). In the Central Plateau there are about 5 million hectares (50,000 sq. km) of active sand dunes (Tavakoli, 1982). During the 1960s, new technologies were brought in, such as water pumps, dam construsction and use of tractors. This was accompanied by a land reform program and business investment in agriculture. The new technology changed the socio-economic structure of the villages of the area. It made possible an increase in cultivated land and supported larger herds of livestock. In the long run however, it led to overgrazing and soil exhaustion, erosion and desertification. Sand storms began to become a problem in the region. Therefore, sand dune encroachment and sand storms were recognized as a national major environmental problem in Iran (Kardavni, 1980; Tavakoli, 1982). In 1965, the Iranian government started their large scale sand dune and sand storms stabilizing programme. They adopted both biological and combined mechanical and biological means (Tavakoli, 1982).

The mechanical means included the use of a petroleum mulch which was used as pre-stabilization treatment. The petroleum mulch was used after seeding or planting, in order to bind the sand particles, conserve moisture and absorb solar heat, which speeded up germination (Tavakali, 1982). In this project various types of species such as Haloxylon persicum, H. aphylla, H. amodendron, H. salicornicum; certain tamarisks (Tamarix stricta and T. pallissii); some acacias (Acacia farnesiana, and A. arabica); the mesquite bushes (Prosopis juliflora and P. epicigera); shrubs such as 'scambil' (Calligonum comosum); the halophytes Atriplex conescens and A. halimus; and grass species of the Panicum spp., Aristida spp. and Seddlitsia spp. were used (Tavakoli, 1982). These types of species have been selected according to their resistance to harsh environment conditions, particularly drought, and the high ranges of temperature.

Thirdly, a Saudian experiment is considered. This one was carried out in the eastern part of Saudi Arabia where active sand dunes and sand and dust storms occur frequently (Abdul Wahid, 1982; Al-Sery, 1984; Abolkhair, 1984). The main sources of the sand and dust are from nearby deserts such as An Nafad, Ad Dahna, Al-Jafurah and Rub Al-Khali (Empty Quarter) (Al-Gupame, 1981; Holm, 1960; Al-Sery, 1984; Abolkhair, 1984; Abdul Wahid, 1982). All these deserts affect the cultivated lands and villages of the Al-Hasa oasis, and the effects are also related to the main wind directions which are from the north and north west (Al-Sery, 1984; Abolkair, 1984; Abdul Wahid, 1985).

The amount of sand which moves towards Al-Hasa is estimated at about 230,000 cubic metres per year (Al-Sery, 1984; Abdul Wahid, 1982), and it moves southwards at a rate of 10 to 25 metres annually (Abdul Wahid, 1982; Abolkahri, 1984). Some of the older people of Al-

Hasa claim that more than half of the cultivated lands which used exist has been covered by sand (Abolkhair, 1984). The economic importance of this area is that it is one of the most important agricultural areas and oil producers in Saudi Arabia (Abolkhair, 1984; Abdul Wahid, 1982; 1985). There are two types of sand movement here, sand drift and barchanoid mass movement. Sand drift is more dangerous than the mass movement because sand drift movement is faster and may cover longer distance (Abolkhair, 1984). It has been noticed that the sand drift amount reduced dramatically after rainfall due to the increase of soil moisture (Abolkhair, 1984). Many methods are used to stabilize the sand in the region:

1) Oil Mulching: This method has been used since the early days of oil exploration in the region by oil companies. It is used to protect roads which are liable to be covered by sand (Abolkhair, 1984; Al-Sary, 1984; Shakatrh and Osman, 1984). Oil mulching is still used by the Ministry of Transportation in Saudi Arabia to protect main roads between the cities (Al-Sary, 1984). The main advantage of oil mulching is that it is a quick method of stabilizing the sand. However it is costly, especially for non-petroleum countries.

2) Artificial Barrier: This method uses solid barriers such as wooden poles, metal plates, barrels or palm leaves (Al-Sery, 1984; Abolkhair, 1984; Shakatrh and Osman, 1984). Such barriers reduce the wind velocity over the first metre above the ground and thus trap sand behind them. In Tunisia, for example, iron bars with 10-12 mm in diameter, and about 30 cm apart, are used. These bars are then inter-woven with the palm leaves (Shakatrh and Osman, 1984). Periodically the trapped sand needs to be removed from the barriers, otherwise they will be totally buried by the sand and rendered useless.

3) Moving Sand by Mechanical Methods: This method requires manpower and tractors and dump trucks. It is mainly used to remove dust and sand deposit from roads, railway tracks, and buildings **(Plates 8.1, 8.2a, 8.2b, & 8.3)** (Al-Sery, 1984).

4) Plantation (Biological Method): this is one of the most successful ways to stabilize and reduce the hazards of mobile sand and restore the ecological balance (Zhanda and Shu, 1981; Tavakoli, 1982; Shakatrh and Osman, 1984; Abolkhair, 1984). One of the earliest experiments with plantation of shelter-belts in Arab countries was in Tunisia in 1886, when the French Forestry Department tried to stabilize sand dunes in the Dares region (Shakatrh and Osman, 1984). The same approach was used by the Italians in Libya in 1916 to protect roads in the Tripoli area. A project was started in 1929 to stabilize the sand and dust in the Western Desert and southern oases of Egypt (Shakatrh and Osman,1984). Two methods have been used in starting plantations, specifically by the distribution of plant seeds or planting of seedlings. Seeding experiments have been practiced in Libya and Syria. The Libyan experiment was not successful, but the Syrian one was more successful (Shakatrh and Osman, 1984; Sankary, 1986). The Syrian project used the seed of Atriplex spp. and Salsola vermiculata (Sankary, 1986), to establish shelter belts, which have become widely employed.

According to the Arab Centre for the Studies of Arid Zones and Drylands (ACSAD) in 1982 the total area which had been planted in Arab countries was 2.5 million hectares (25,000 sq.km.). Of this area 1.5 million hectares (15,000 sq.km) were in mountain regions, 600,000 hectares (6,000 sq.km) in the marginal zones and 320,000 hectares (3,200 sq.km) used to stabilize sand dunes and form windbreaks (Shakatrh, 1986). The Saudian sand dune control project covers an area

Plate 8-1: Removing sand which has been trapped by the road curb, by mechanical means

Plate 8-2a: Bus shelter on the Ahmadi Maqua road running through Ahmadi desert, buried by sand to seat level. Also, part of the road on the left of the photo has been covered. Part of the Tamarix aphylla trees which is used as shelter belt is also covered, but have survived.

Plate 8-2b: The sand deposits shown in photo 8-2a have been removed by excavator. The annual Kuwaiti government cost of removing sand from the road in 1987 was about 680,496 K.D. (1,360,992 £), and in 1988 was about 730,500 K.D. (1,461,000 £).

Plate 8-3: The fence around the motorway which was built to prevent animals from straying onto the motorway, has become covered by sand and is no longer effective as a barrier, on the right side of the photo. This runs through Jahra governorate desert. The fence has become covered by sand because papers or dead plants become trapped in it. The fence become impermeable and thus sand accumulates rapidly.

of about 4,500 hectares (45 sq km) and involves plantation of about 7 million trees (Abdul Wahid, 1985). The project is divided into two shelter-belt zones, the main shelter belt which is supported by irrigation and the four secondary shelter belts which use dry planting and are dependent on soil moisture (Abdul Wahid, 1982; 1985; Al-Sery, 1984). From field observation it been found that there is soil moisture at a depth of about 20 centimetres to one metre. This level varies from summer to winter (Abdul Wahid, 1982). Prosopis juliflora is planted to a depth of about one metre (Abdul Wahid, 1982). The main shelter belt is about 20 km long and 250 metres in width and each secondary shelter belt is about 5 km long and 400 metres in width **(Figure 8.1)** (Abdul Wahid, 1982; 1985; Al-Sery, 1984). Plantation comprise about 90% of Tamarix spp. and 10% of other trees such as Prosopis juliflora, Eucalyptus ssp., Rizinus communis, Acacia cyanophylla, Casuarina cunnighamia and Parkinsonia aculeata (Abdul Wahid, 1982; 1985).

This project saved about twenty villages from sand drifts and has increased cultivated areas from 8,000 hectares (80 sq.km) to about 20,000 hectares (200 sq.km) (Abdul Wahid, 1982).

Successful management requires that the following points should be considered:

1) Environmental hazard issues should become a part of public awareness (Ondeng'e, 1984)

2) Decision makers should be knowledgeable in all relevant aspects of environmental hazards, such as desertification (Ondeng'e, 1984).

3) There should be a team for desertification control, including experts such as veterinarians, ecologists, management specialists, agriculturalists, agricultural engineers, soil scientists, regional planners, foresters, architects, social scientists and research administrators (Ondeng'e, 1984).

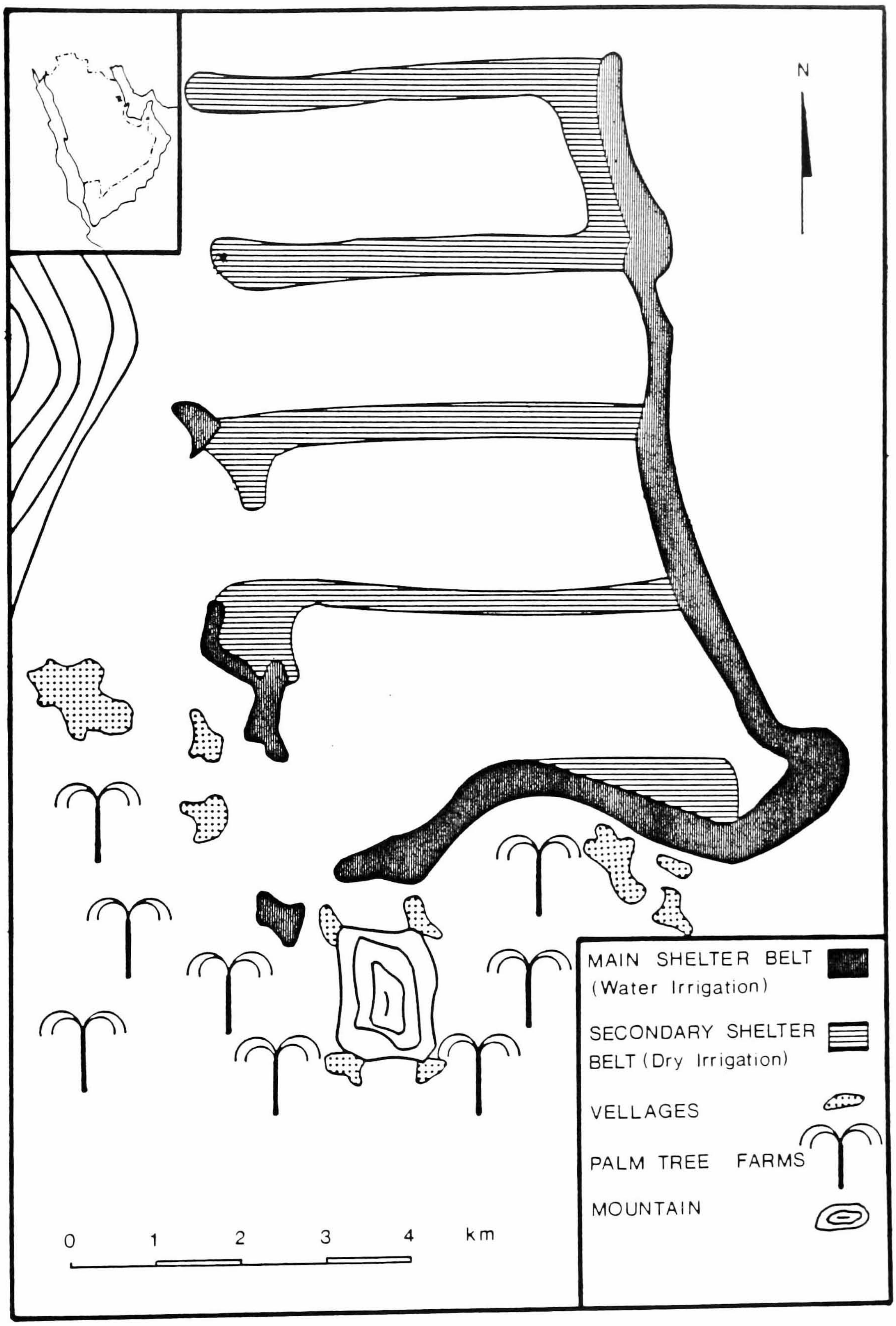


Figure 8-1: The sand control project in Al-Hasa oasis in Saudi Arabia. (After: Abdul Waid, p.6, 1982)

8.3) Shelter Belts in Kuwait:

8.3.1) Introduction:

It has been shown that Kuwait suffers from dust and sand storms particularly during the summer (Al-Shuaby, 1984). The impacts of sand and dust mobility are more evident on the outer-city roads than inner-city roads. It been seen that many of roads out-side cities are buried by sand (Gareeb, 1984). Certain plants are decreasing or disappearing; for example, there is a dramatically decreasing number of Ziziphus memmularia and Rhanterium epapposum individuals in Kuwait (Showrbajy, 1984). Recently the government passed an act which prohibited cutting Rhanterium epapposum, because it was endangered (Sheha, 1984). Therefore, increasing sand and dust activities and decreasing amount of vegetation cover is an ominous sign of desertification (Al-Showrbajy, 1984). A further problem is that desertification is not one of the main issues of public concern. One of the main reasons for this is that the country's economic structure does not depend on use of range lands, therefore it is important to draw the public's attention towards this problem through mass media and education (Ondeng's 1984).

In the case of Kuwait, the biological method of control seems to be the best choice, especially as it has been used successfully by neighbouring countries, such as Iraq (Gati, 1984), Iran (Tavakoli, 1982; Kardovri, 1980) and Saudi Arabia (Abdul Wahid, 1982). Overall, the government spends monthly about 56,708 Kuwaiti dinars (£113,146) in 1987 and 60,875 Kuwaiti dinars (£121,750) in 1988 to pick up dust and sand deposits from the roads (pers. comm., 1988). The cost of cleaning motorways of dust deposits by the contractor of Ministry of Public Works in 1987 was 20,833 Kuwaiti dinars (£41,666) and in 1988 was 25,000 Kuwaiti dinars (£50,000) (pers. comm., 1988).

The main advantage of shelter belts in arid and semi-arid environment areas are, as follows:

1) Shelter belts reduce strong winds which cause dust storms by 50% or more. Also the plant leaves can act as a "filter" cleaning dust particles from the air (Al-Mutawa, 1985).

2) Shelter belts protect soil and sand from being eroded by strong winds (Goudie, 1986; Salem, 1988)

3) Using shelter belts along the highways and roads help in decreasing noise levels (Al-Mutawa, 1985).

4) Shelter belts increase the soil moisture level and humidity. On the other hand, they reduce evaporation and evapo-transpiration rates (Al-Mutawa, 1985).

5) Shelter belts can used as a sand stabiliser to protect oases, roads, canals, settlements, oil pipe-lines, plants, and farm lands, from sand drift (Babaev; Orlovsky; and Kharin, 1988)

6) Shelter belts may be used as a source of grazing for the livestock in a controlled and self-sustaining way (Salem, 1988).

8.3.2) The Main Problems Facing Shelter Belt Projects:

Dryness, high temperature and low rainfall are the main characteristics of Kuwait's climate (Hassan and Al-Abdul Jalleel, Undated; Bahbahny, 1985; Abass, Awad and Hassain, Undated). The main obstacles of planting the shelter belt in Kuwait are related to these and are as follows:

1) Lack of Water: The shortage of water in Kuwait is a long term problem. The amount of rainfall is about 110 mm annually. This is not enough to establish such a programme of shelter belt planting. In the case of Iran, Iraq and Saudi Arabia more water is available than in

Kuwait, where the fresh water supply is produced by desalination from sea-water, and is only used for domestic needs (Abass, Awad and Hassain, Undated; Ministry of Public Works, Undated). Brackish water (3000-10,000 part per million) from undergound sources, is used for agricultural purposes (Al-Feel and Al-Mutawa, 1983; Hassan and Al-Abdul Jalkel, Undated; Abass, Awad and Hassain, Undated).

Therefore, the only available water source remaining is recycled sewage water. There are several sewage water treatment plants built for shelter belt irrigation purposes (Hassan and Al-Abdul Jalleelun, Undated; Abass, Awad and Hassain, Undated) **(Table 8.2)**.

Sewage Water Treatment Plant	Water Treated Production (mill.gallons/day)
Ardiya Plant	20
Coastal Village Plants	22
Jahra Plant	14
Failaka Island Plant	2

Table 8.2: Treated sewage water plants production in Kuwait (million gallons/day). (After: Abass, Awad and Hassain, p. 12, Undated).
*Multiply by 4.546 to convert to litres.

Shatt Al-Arab Project: One of the oldest major project to supply fresh water to Kuwait was to utilise the Shatt Al-Arab. It is about 96 km from Kuwait. This was discussed by first the Kuwaiti and Iraqi governments in 1954. Iraq agreed to supply Kuwait 100 million gallons daily (454.6 million litres), but due to difficulties the project was withdrawn (Al-Abdul Razzq, 1974). In 1963 the two governments started negotiations again. In 1965, they awarded the contract to the lowest bidder and the main points which had to be considered were (Al-Abdul Razzq, p.p. 97, 1974):

1) Suggesting suitable sites in Iraq from which to abstract water;

2) Quantity of water supplied to be about 120 millions gallons daily (545.5 million litres), 50 millions gallons (227.3 million litres) for drinking and domestic uses, and 70 millions gallons (318.2 million litres) for agriculture purposes.

3) Allocation of storage sites in Kuwait.

4) Allocate and suggestion of new agriculture sites.

Unfortunately this project is still under discussion and negotiation.

2) Poor Soil: Kuwait soils are poor in organic matter and contain high amounts of salt (Al-Feel and Al-Mutawa, 1983; Abass, Awad and Hassain, (Hassan and Al-Abdul Jalleelun, Undated; Abass, Awad and Hassain, Undated).

3) Protection Act: In the United States the Clean Air Act, Clean Water Act and Endangered Species Act are showing positive results (Moran, Morgan and Wiersma, 1980). In Kuwait shelter belts need such an act to give protection by law from both humans and animals.

8.3.3 Shelter Belt Projects in Kuwait:

One of the main purposes of shelter belt plantation is to reduce dust and sand storm hazards on roads and buildings, and they are as follows **(Figure 8.2)**:

1) Jahra Road Shelter Belt: The total area which this project covers is about 1700 donoms (1.7 sq. km) and was started in 1966. 70,000 trees were planted, most of them were *Tamarix aphylla* and *Proposis spp.* (Ministry of Public Works, Undated). It has been irrigated by untreated

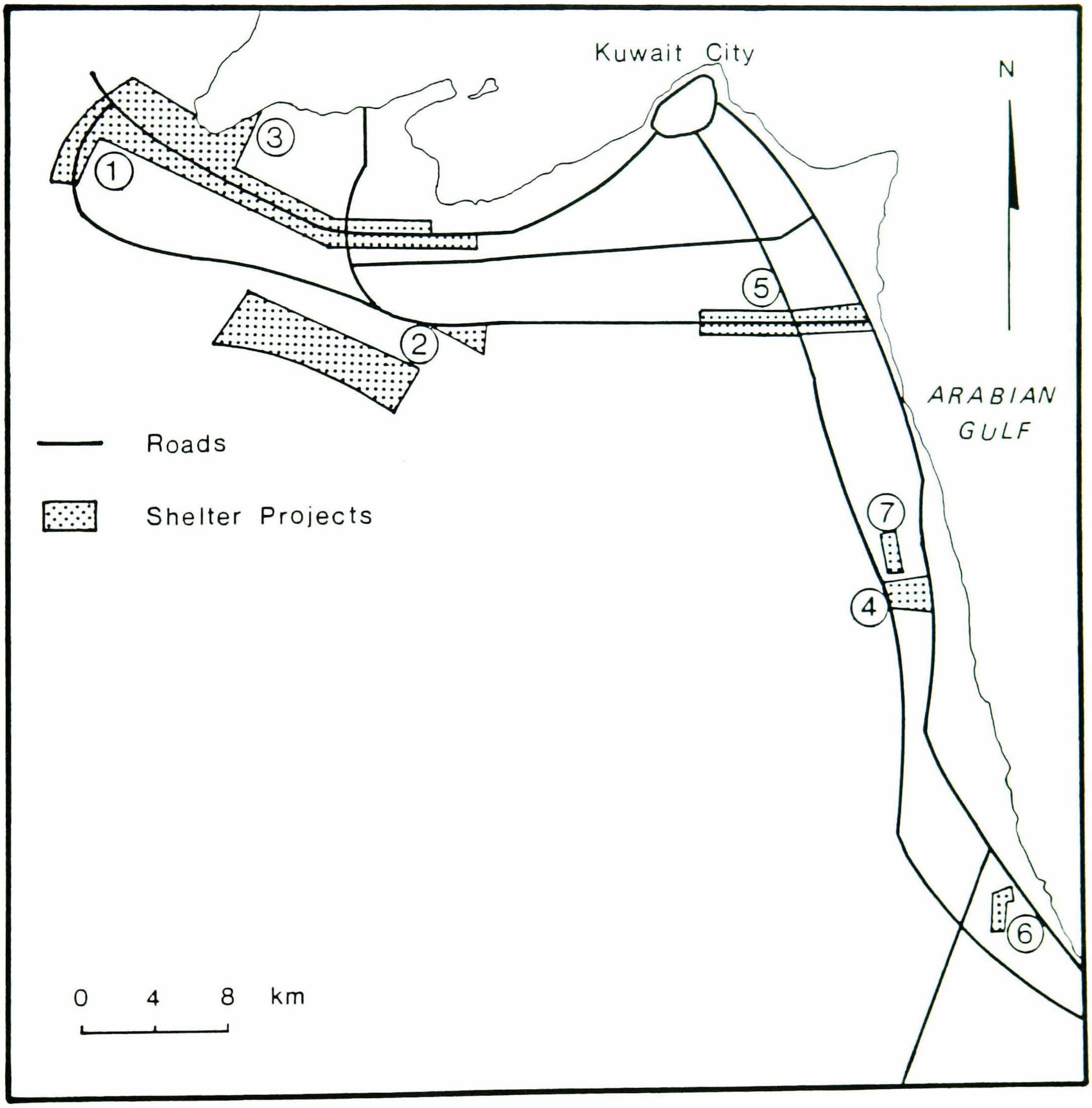


Figure 8-2: Present shelter belt projects in Kuwait.

(After: Abass, Awad and Hassian, p.17, Undated) sewage water (Abass, Awad and Hassain, Undated).

2) Sulaibiya and Shadadiya Project: These two areas are part of a large scale plantation project which covers an area about 50,000 donoms (50 sq. km) and was started in 1968 (Ministry of Public Works, Undated). The Sulaibiya part covers an area of 12,000 donoms (12. sq. km) and the Shadadiya covers an area of 8,000 donoms (8 sq. km). Both of these are irrigated by treated and untreated sewage water (Abas, Awad and Hassain, Undated).

3) The Spring Camping Project: This project covers an area of 50,000 donoms (50 sq. km) and was started in 1969. It extends from Doha to Jahra. One of the aims of this project is to protect Jahra City from the northerly dusty winds (Ministry of Public Works, Undated). There were 20,000 hectares (20 sq. km) planted with various types of trees, such as Tamarix aphylla, Proposis spp., Acacia salicina, Ziziphus spina and Eucalyptus spp. (Ministry of Public Works, Undated).

4) Subahyia Project: This started in 1969 and covers an area of about 3,200 donoms (3.2 sk. km). There were 100,000 trees planted of various type (Ministry of Public Works, Undated). Untreated sewage water was used for irrigation **(Plate 8.4)** (Abass, Awad and Hassain, Undated).

5) Sixth Ring Motorway Project: The main purpose of the project is to protect the Sixth Ring Motorway from dust and sand storms. It started in 1970 and the total area of the project is about 1100 donoms (1.1 sq. km). 50,000 trees have been planted (Ministry of Public Works, Undated). These trees were planted in eight lines at each road side (Abass, Awad and Hassain, Undated).

Plate 8-4: Using untreated sewage water to irrigate a shelter belt in Subahiya city.

6) Um Al-Himan Project: The project started in 1980 to protect Um Al-Himan village from dust and sand storms **(Plate 8.5)**. The shelter belt is planted around the village on three sides , north, west and south. The total area of plantation is about 2,000 donoms (2 sq. km) (Ministry of Public Works, Undated).

7) Reqa Project: This shelter belt is planted on the western side of Reqa City in order to protect it from dust storms in the summer and from rain torrents in the winter, due to the west to east slope of land (Ministry of Public Works, Undated; Abass, Awad and Hassain, Undated). The plantation started in 1972 and covers an area of about 900 donoms (0.9 sq. km). 40,000 trees were planted in eight lines 3 km long. The trees were irrigated by untreated sewage water (Ministry of Public Works, Undated; Abass, Awad and Hassain, Undated).

8.3.4) Plants Used for Shelter Belts in Kuwait:

The above projects show that the best type of plants for the shelter belts or sand stabilisation are those which are adapted to survive in this severe condition of the environment. In Kuwait the main tree species which are used for plantation programmes are:

1) Tamarix aphylla (Tamaricaceae): It is used in most of the shelter belt projects. It is resistant to drought and salt. It can survive with brackish water and treated or untreated sewage water for irrigation. It is used to stabilise mobile sand and reduce wind velocity (Sheaha, 1984; Ministry of Public Works, Undated; Abass, Awad and Hassain, Undated).

2) Ziziphus spp. (Rhamnaceae): It is an evergreen tree of the hot and dry regions. It reaches about 10-12 metres in height and lives for a long

Plate 8-5: A shelter belt located on the north west of Um Himan village. It has been planted in multiple rows to protect the village in the right distance from dust and sand storms.

time typically about 100 years. It is a very common tree in Kuwait, and brackish, treated sewage or fresh water can be used for its irrigation (Sheeha, 1984; Ministry of Public Works, Undated).

3) Acacia salicina (Leguminosae): This is an Australian evergreen tree. It is adapted to hot and dry regions. Treated sewage and brackish water may be used for irrigation, but for better and faster growth the use of fresh water is preferred (Sheeha, 1984; Ministry of Public Works, Undated).

4) Eucalyptus camaldulensis (Myrtaceae): This is an evergreen tree which was brought from Australia. It can reach 12 metres in height with its first four years. Brackish and treated sewage water may be used for irrigation. (Ministry of Public Work, Undated; Sheeha, 1984; Abass, Awad and Hassain, Undated).

CHAPTER NINE: CONCLUSION

Dust phenomena have been defined in Kuwait as occurring whenever the horizontal visibility range is reduced to below 1000 metres due to dust present in the air as a result of strong winds. Dust storms occur at any time throughout the year, but are more frequent during the summer, especially in June and July (17.8% and 16.8%). There are four types of dust which have been reported by the Meteorological Department at Kuwait Airport. These are dust/sand storm, rising dust, suspended dust and haze. The dust storms in Kuwait are mostly associated with dry and hot northerly and north-westerly winds which are locally named "Shamal".

In order of significance the factors which generate dust storms are: availability of strong winds, dust source, incoherent sand surface layer, lack of rainfall, lack of vegetation cover and some negative human activities.

The dust which occurs in Kuwait comes from two main sources; local sources and regional sources. The most important local sources are Al-Huwaimliyah, Umm Negg Sand Sheet and the southern and northern coast area. The regional source mainly comes from surrounding desert such as An Nafad, Ad Duhna, Rub Al-Khali and Western Iraqi Desert. All these sources, local and regional, surround the country in all directions, except from the east, the Arabian Gulf; but the most significant dust source is the Western Iraqi Desert where most dust storms originate. **(Plate 9.1)**.

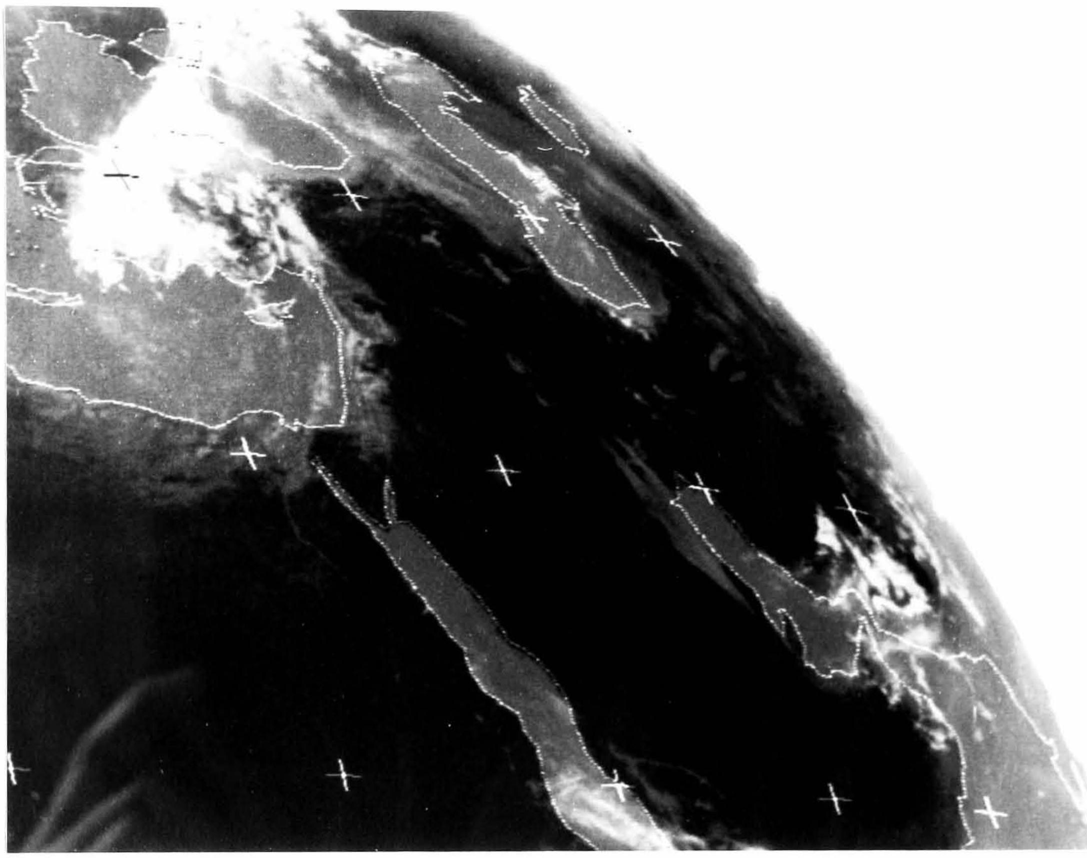


Plate 9-1: MET 2 satellite image of a dust storm cloud over Kuwait on 30 July 1984. The source of this cloud is the southern part of Iraq. According to meteorological data for that day, maximum temperature was 46°C and minimum was 32°C and maximum relative humidity was 14% and minimum was 5%. The prevailing wind direction was north westerly and mean wind speed was 8.8 m/s. The maximum gust was at 10.20 am of wind speed 15.6 m/s from north west direction. the lowest visibility reported in Kuwait was 20 meters.

This study has investigated and measured dust impacts on the following aspects of the environment:

1. Dust impacts on transportation
2. Dust impacts on buildings and homes
3. Dust impacts on people's health.

1) Dust Impacts on Transportation Methods: The main effect of dust storms on the transportation methods is reduction in horizontal visibility. In the case of normal dust storms the visibility is below 1000 metres, though it may fall below 200 metres in cases of severe dust storms and to zero in very severe dust and sand storms. In these circumstances it is very dangerous for a pilot to land at the airport. Therefore many flights are delayed due to poor visibility caused by dust cloud. Drivers, like pilots, suffer from poor visibility which in many cases plays an important role in causing traffic accidents. It has been found that there were strong correlations between the number ofdays with visibility of less than 500 metres and the number of dust storm days (+0.772 for 23 year period (1962-1985)). There were significant correlations between the number of days with visibility less than 4 km and the number of dusty days (excluding haze) (+0.898). However correlation between road accidents and the number of dust type days could not to established because of the following factors:

1) Accident reports did not include the precise weather condition at the time of the accident. Therefore when impaired visibility was a factor, its cause may be dust, fog, or rain.

2) The road accident report did not state the horizontal visibility range.

3) There are other factors involved in the cause of road accidents, such as careless driving and excessive speed.

Correlations were calculated between the number of accidents with the number of rainy days, quantity of rainfall and number of foggy days. Generally, these correlations were weak. In the same manner, correlations were made between the road accidents and the horizontal visibility range. The following correlations were significant, that between road accidents and visibility range of 0.51-1 km Kuwait was +0.696, less than 1000 metres was +0.486 and less than 4 km were +0.511. It appeared from field survey that most of the accidents had been caused by dust storms and fog was the next most frequent cause. The effect of dust on parts of cars has also been investigated. The main parts which were badly affected by sand storm particles are front facing, such as the front paintwork of the car, its windscreen, and front lights.

2) Dust Impacts on Houses and Buildings: The analysis of dust and sand storm effects on buildings were less clear and satisfactory than those on effects on cars. It is likely that this is because all homes in Kuwait are built with concrete. Therefore, the erosive effect of sand storm takes a longer time to be significant; and renewing the buildings every ten or eight years or so, a normal occurrence, destroys any evidence. But, during dust storms, particles enter bedrooms, living rooms and kitchens. Therefore, the dust and sand storm effects on these rooms were noticeable. The areas which were most affected by dust and sand storms are exterior windows, gardens and exterior house paintwork. It was found that the occurrence of open spaces with bare ground around houses and buildings increased the amount of dust in the air. Balconies increased the amount of dust entering flats. It was found that gardens with planted vegetation have a significant role in reducing the effect of dust on houses. There were significant correlations between the energy and water consumption and dusty days in Kuwait. For instance, the correlation coefficient between average electricity peak load and dusty days with haze was +0.91, that between fresh water consumption and such days was +0.83 and between brackish water consumption and such days was +0.92. This indicated higher use of air conditioning and water for washing during dust activity periods.

These correlations were still significant of the allowance for the effect of temperature and the trend in utility consumption.

3) Dust Impacts on Human Health:. Harmful effects on human health occur as a resulting of inhaling fine dust particles. These cause many types of allergies and illnesses related to the organic and non-organic material content in the dust. The organic materials include pollen, hair, bacteria, fungi and a variety of fragments of plants and animals. Non-organic materials are mainly silicate minerals, clay and volcanic dust. The most common allergy types caused by dust are those related to the respiratory system. It has been found that the nose is the part of the body most affected by dust storm, followed by the eyes and chest. Again lack of precision in medical records makes it difficult to test relationships between illnesses and dust phenomena.

4) Methods of Management for the Dust Problem: The environmental hazard of dust phenomena cannot be permanently reduced as long as the generating factors exist. These factors have been identified as strong winds, incoherence of soil, and sparse vegetation cover. So, in order to reduce the dust hazard, these factors should be modified. The wind system is difficult to modify except at very small, local scales. But the other factors are easier to control. One of the best methods to control and reduce the dust storm hazard is by tree and shrub plantation. The plants stabilise the surface layer of sand and increase total vegetation cover. This method has been successfully applied in neighbouring countries which suffer from dust hazards, such as Iraq, Iran and Saudi Arabia.

Many shelter belt projects are currently underway in Kuwait. In these projects irrigation is set up and both treated and untreated sewage water is used. The main types of plants which are used in these projects are Tamarix aphylla, Ziziphus spp., Acacia salicina and Eucalyptus camaldulensis. Shelter belts in Kuwait were first established in the second half of the 1960's. As yet there have been no published evaluation studies of these experiments in Kuwait, through general observations indicate that they are successful.

9-2) Critique of the Research Programme:

There are many issues revealed in this study, which could be the subject of further studies and investigation. These include:

1) Generally, there are little long term climatic and other data available. The longest data term which were used are the climatological data with duration of about twenty years. In some cases however the available data covered for one, two or three years only. Examples include data on allergies and illness, and questionnaire data collected by the author on environmental impacts, for example the Kuwait Allergy center established in 1984. Therefore, these short term data are insufficient for rigorous statistical treatments to establish trends and relationships.

2) The climatological data does not distinguish between sand storms and dust storms. Even the published materials by the Meteorological

Department in Kuwait (Al-Kulaib and Safar) did not make clear distinctions between them. In fact, they are two different phenomena. The particles in the sand storm plays a more significant role in the erosion process than those of the dust storm. In residential areas sand storms are not so evident, because they are trapped by marginal buildings and are unable to rise up in the air beyond a few metres above the ground. Therefore, sand storms effects are stronger outside the city than in the city itself.

Information on road accidents were not reported according to weather conditions. So statistical analysis cannot distinguish the effects of other factors, such as rain, foggy days and careless driving. For example, during April and May, when the sarrayat season (local thunderstorms) begin, such storms are often accompanied by severe dust storms and have short duration but are accompanied by intense rainfall which reduces the visibility to zero. Both the severe dust storms and heavy rainfall play a major role in road accidents. Therefore it is hard to know the extent to which each is a cause of the accident, without recording the weather condition, and drivers' and police comments on each accident.

3) The energy load average and water consumption data in Kuwait includes data for both houses and factories. The factories consumption of energy or water should be relatively stable throughout the year, since they tend to use the same amount of water and energy consumption per month. But household consumption differs markedly from month to month. Therefore the weather's effect on the household consumption of water and energy is greater than that of the factories. Unfortunately, official monthly data on water and energy consumption does not exist because the Ministry of Electricity and Water have adopted an annual

average system for payment of bills. This system is based on two meter readings during the year. The total of two readings are divided into twelve months. So, the consumer pays the same amount each month until the end of the year. The next year's payment, depends on the consumption of the previous year. If the consumer then uses more energy and water than in the previous year, his average amount of payment will increase (or vice versa). Therefore, to find out the monthly consumption of electricity and water used by households, field observations over at least two years are needed. This could be by asking the householders to record their consumption of water and electricity each month which may provide useful data.

4) The dust effect on the houses and buildings would be clearer if further interviewing were done. Such interviews should distinguish between two groups of houses, those that were badly affected by dust storms and those which were less affected, in order to recognize the degree of dust hazards, and to identify geographical patterns of effects.

5) Interviewing of patients who reported allergies due to dust storm is needed to clarify how dust affects health. Presently data on this is not precise, nor can it be subjected to statistical analysis.

9-3) Recommendations:

Following this research there are certain recommendations relating to the reduction of dust hazard and its related effects:

1) Reduce in size or omit balconies in houses or flats, since they increase amount of the dust which enters the house.
2) Protect windows and doors by using screen protection to reduce the effects of dust.

3) Encourage householders to plant around their houses and in empty spaces in each neighbourhood.

4) Limiting spring camping to certain areas in order to protect natural vegetation.

5) Establish a research unit in order to study and improve the quality of native wild plants, which may be used as sand stabilisers.

6) Protect roads, especially out-of-city roads, from sand and dust storms by establishing several lines of trees to act as windbreaks, to improve the visibility on these roads.

7) Establish regional councils for dust storm hazard control, because all the Gulf nations (Iraq, Saudi Arabia, Kuwait, Bahrain, Iran) suffer from the dust hazards. These councils have common interests in dust generation, control and impacts at a regional scale.

8) Establish a fieldwork team to investigate dust hazard and control methods in Kuwait. This team should include geographers, geologists, ecologists, planners, botanists, doctors and engineers working in a cooperative project. Such a team should liaise with the countries which use advanced techniques in controlling dust such as the United States and Australia.

9-4) Further Studies:

In order to continue the research further, more investigation about environmental problems related to the dust hazard in Kuwait is needed. These studies need data to be collected from the field and will need to be observed for period of at least two years. Such a period are necessary to allow the separation of the dust hazard effects and other variable factors such as rainfall and fog. These further studies requred are as follows:

1) Oil production is the main source of national income of Kuwait. The

oil fields and pipe lines run through the desert and frequently are covered by sand, because they trap moving sand and dust. Workers who check the oil centres, field and oil pipes suffer from illnesses or are otherwise affected by sand and dust storms, because they work out-doors in the desert. Measurement of the degree of dust and sand storms hazard on these facilities and workers is required.

2) Dust and sand storms impact on houses and building need further investigation. Such investigation is required to follow up dust and sand storms impact on buildings through a series of monitoring programmes based on selected areas.

3) In order to follow up and investigate the effects of dust and sand storms on vehicles it is necessary to follow up a specific number of individual cars, perhaps two or three hundred cars, in order to find out and measure the degree of hazard and the cost of parts for repairs related to dust damage.

4) Dust effects on plants and agriculture lands in Kuwait need further investigation. Dust and sand storms have an important effect in causing damage to plants and fruit. To estimate the amount and nature of this damage it will be necessary to measure production in terms of both quality and quantity in the agricultural areas in Kuwait.

5) Dust storm particles, especially the fine particles, play an important role in respiratory system problems of people. Dust causes allergies and other illnesses which have not been yet

precisely investigated. Therefore, cases of apparent allergic and other dust-related illnesses (at least two or three hundred cases) should be followed up in order to measure and investigate the dust role and hazard on people's health.

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APPENDIXES

Appendix I

QUESTIONNAIRE
Dust Phenomena in Kuwait and its Environmental Impacts

PART ONE:

1) PERSONAL INFORMATION:

1- Gender

1) Male 2) Female

2- Nationality

1) Kuwaiti 2) Non-Kuwaiti

If not Kuwaiti, please specify...

For non-Kuwaiti answer 3 to 4:

3- How long have you been in Kuwait?

1) 1-2 years 2) 2-4 years

3) 4-8 years 4) 8-12 years

5) More than 12 years

4- Do you have in your own country dust storms or any type of (airborne) dust?

1) Yes 2) No 3) Don't know

(If Yes, answer 5)

5- Do these occur more than Kuwait, or less?

1) More 2) Less 3) Don't know

6- How old are you?

1) Less than 20 years 2) 20-30 years

3) 30-40 years 4) 40-50 years

5) More than 50 years

7- Do you think dust occurs more frequently at the present time than 20 years ago?

1) Present 2) 20 years ago 3) I don't know

PART TWO:

2) DUST AND HOUSE:

1- In which governorate is your house located?

1) Capital 2) Hawalli 3) Ahmadi 4) Jahra

2- How long have you been living in your current house?

1) Less than one year 2) 1-2 years

3) 2-4 years 4) 4-8 years

5) 9-12 years 6) more than 12 years

3- What type of house are you currently living in?

1) Villa 2) Traditional/Limited income houses 3) Flat

(If Flat, answer 4-6)

4- In which floor (level) is your flat?

1) Ground 2) First 3) Second 4) Third

5) Fourth 6) Fifth 7) Sixth 8) More than sixth level

5- How many balconies do you have in your flat?

1) One 2) Two 3) Three 4) More than three

6- Do you think the balconies tend to increase the amount of dust entering your flat?

1) Yes 2) No 3) Don't know

7- Is there an empty space (bare ground) around your house or building?

1) Yes 2) No

<u>(If Yes, answer 8)</u>

8. Does this bare ground produce dust?

1) Yes 2) No 3) I don't know

9- How badly does the dust affect the following parts in/of your house? (please put (x) in appropriate space)

House Parts	I don't Know	Very Little	Little	Medium	Badly	Very Badly
1) Exterior windows						
2) Exterior house-paintwork						
3) Exterior door paintwork						
4) Water tank						
5) Garden						
6) Electrical equipment (TV, radio, etc.)						
7) Carpets						
8) Furniture						
9) Living Rooms						
10) Bedrooms						

10- Do you have a garden in/around your house?

1) Yes 2) No

(If Yes, answer 11-13)

11- Does the garden have any affect on reducing the amount of dust entering your house?

1) Yes 2) No 3) I don't know

12- Are there short or tall trees in or around your garden?

1) Tall 2) Short

13- Please mention the type of name of these trees?

....

PART THREE:

DUST AND CAR:

(If you have a car, answer this part, if not, go to Part 4).

1- For how long have you been driving a car?

1) less than one year 2) 1-2 years 3) 2-4 years

4) 4-8 years 5) 8-12 years 6) More than 12 years

2- How badly does dust affect the following parts of your car?

(please put (x) in appropriate space)

Car Parts	I don't Know	Very Little	Little	Medium	Badly	Very Badly
1) Front windscreen						
2) Front lights						
3) Car's front paintwork						
4) Rear window						
5) Rear lights						
6) Car's engine						
7) Car's seats						
8) Car's gauges						
9) Car's paintwork in general						
10) Engine air filter						

3- Have you had any accident(s) during the dust storms within the last five years?

1) Yes 2) No

(If Yes, answer 4-9)

4- What type of accident did you have?

1) Car with car   2) Car with person   3) Car with animal

4) Car with solid material (e.g. lamp-post, traffic lights).

5- How many times have you had an accident(s) within the last five years?

1) Once   2) Twice   3) Three times

4) Four times   5) More than four times

6- How many times have you had an accident(s) within the last five years during a dusty day?

1) Once   2) Twice   3) Three times

4) Four times   5) More than four times

7- How badly dmaged was your car?

1) Very seriously damaged   2) Seriously damaged

3) Less than serious   4) Slight damage

5) Very slight damage

8- Did you sustain any injuries?

1) Yes   2) No

9- On which type of road did the accident(s) happen to you?

1) Motorway   2) Main Road   3) Secondary road

10- Which of these weather conditions have a major role in causing accidents on motorways?

1) Fog   2) Dust storms (Toze)   3) Rain

11- Which of these dust types have a bad effect on you while you are driving?

1) Dust storm   2) Suspended dust   3) Other types

12- Is it easy to concentrate on roads during dusty days?

1) Yes   2) No   3) I don't know

13- Is it easy to control the car during a dusty day?

1) Yes   2) No   3) I don't know

14- Do you lose your sense of direction during dusty days?

1) Yes   2) No   3) I don't know

PART FOUR:

DUST AND HEALTH:

1- Do you have any type of allergy caused by dust?

1) Yes   2) No

If Yes, give the name ....

2- Does any member of your family have any type of allergy caused by dust?

1) Yes   2) No   3) I don't know

If Yes, give name ....

3- Is this allergy caused by air, hereditary conditions, or by both?

1) By air   2) Hereditary diseases   3) Both

4- Do you suffer from any type of illness which is made worse during dusty days?

1) Yes 2) No

If Yes, give name ....

5- Does any member of your family suffer from any type of disease made worse during dusty days?

1) Yes 2) No

If Yes, give name ....

6- How badly does dust affect the following parts of your body (please put (x) in appropriate space)

Body's Parts	I Don't Know	Very Little	Little	Medium	Badly	Very Badly
1) Eyes						
2) Nose						
3) Face						
4) Ears						
5) Skin						
6) Throat						
7) Chest and respiration						

7- Have you suffered from any type of illness caused by dust in the last five years?

1) Yes 2) No 3) I don't know

If Yes, give name ....

8- Who is most affected by dust?

1) Children 2) Youths 3) Adults

9- Does dust make your breathing difficult?

1) Yes 2) No 3) Sometimes

10- Does dust put you in a bad mood?

1) Yes 2) No 3) Sometimes

Appendix II

Distribution of Questionnaire
Respondents by Maps
over Governorates
in Kuwait

Part one:
General Information

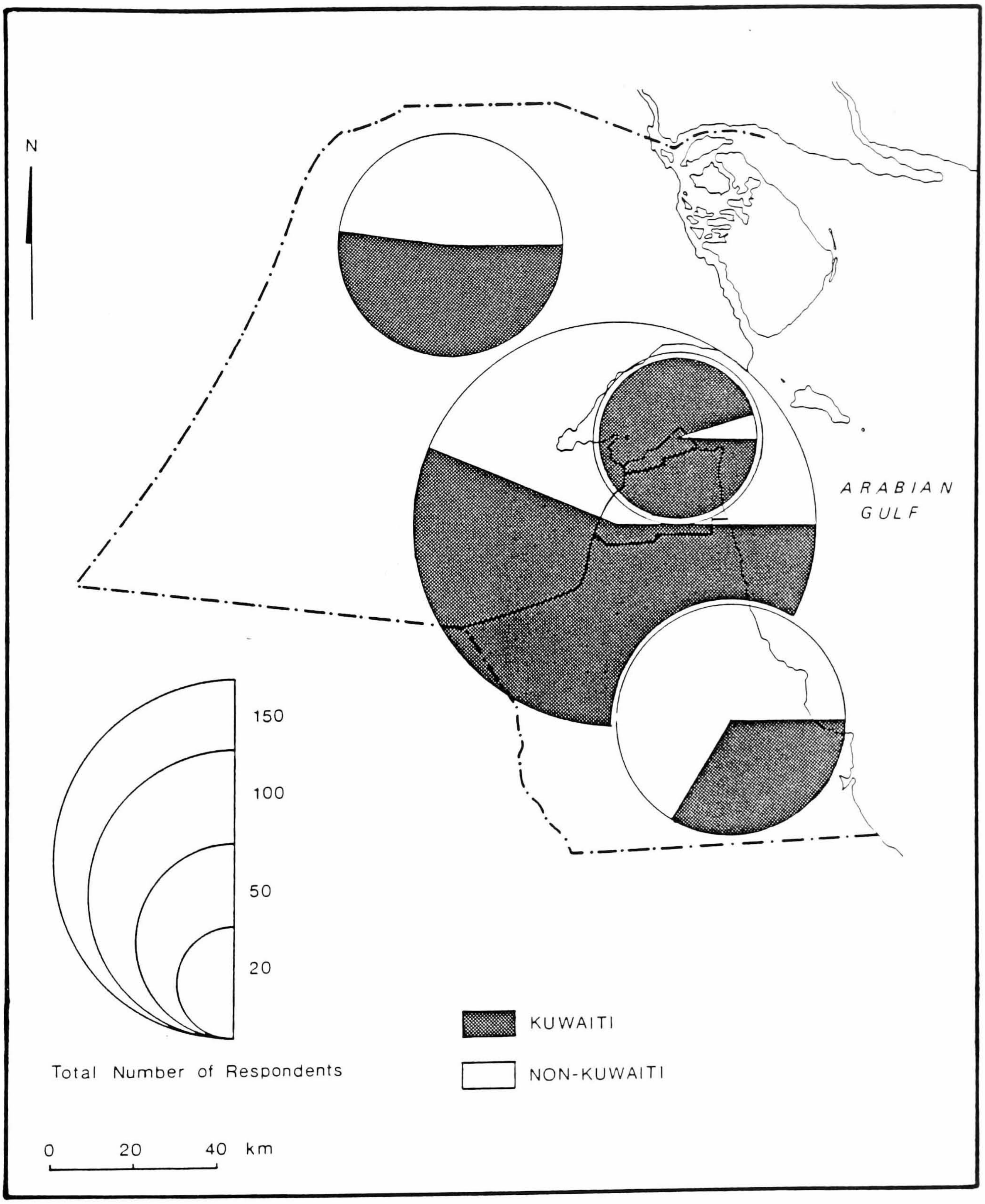

Figure 1: Distribution of Kuwaiti and non-Kuwaiti respondents by governorates in Kuwait.

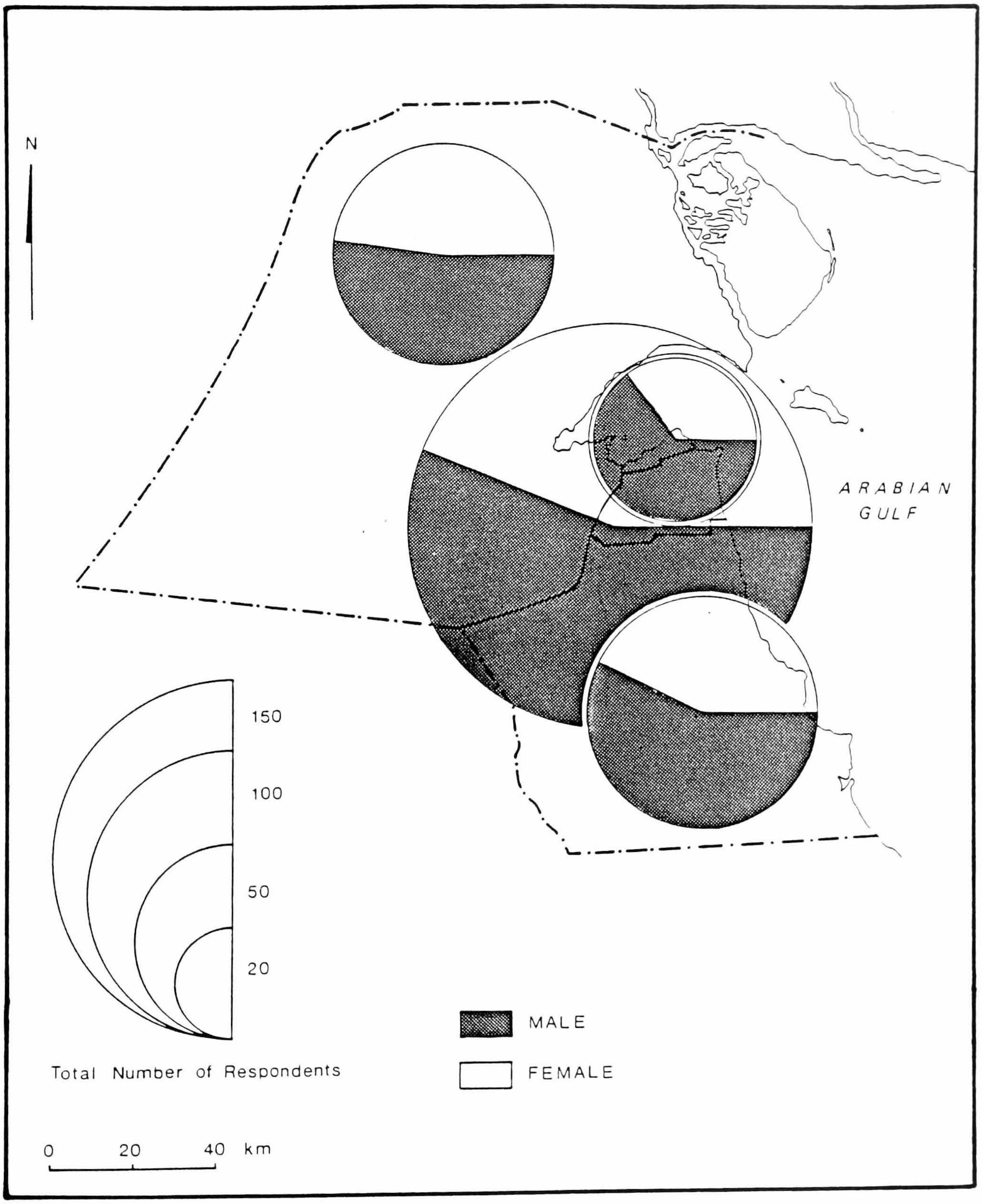

Figure 2: Distribution of male and female respondents by governorates in Kuwait.

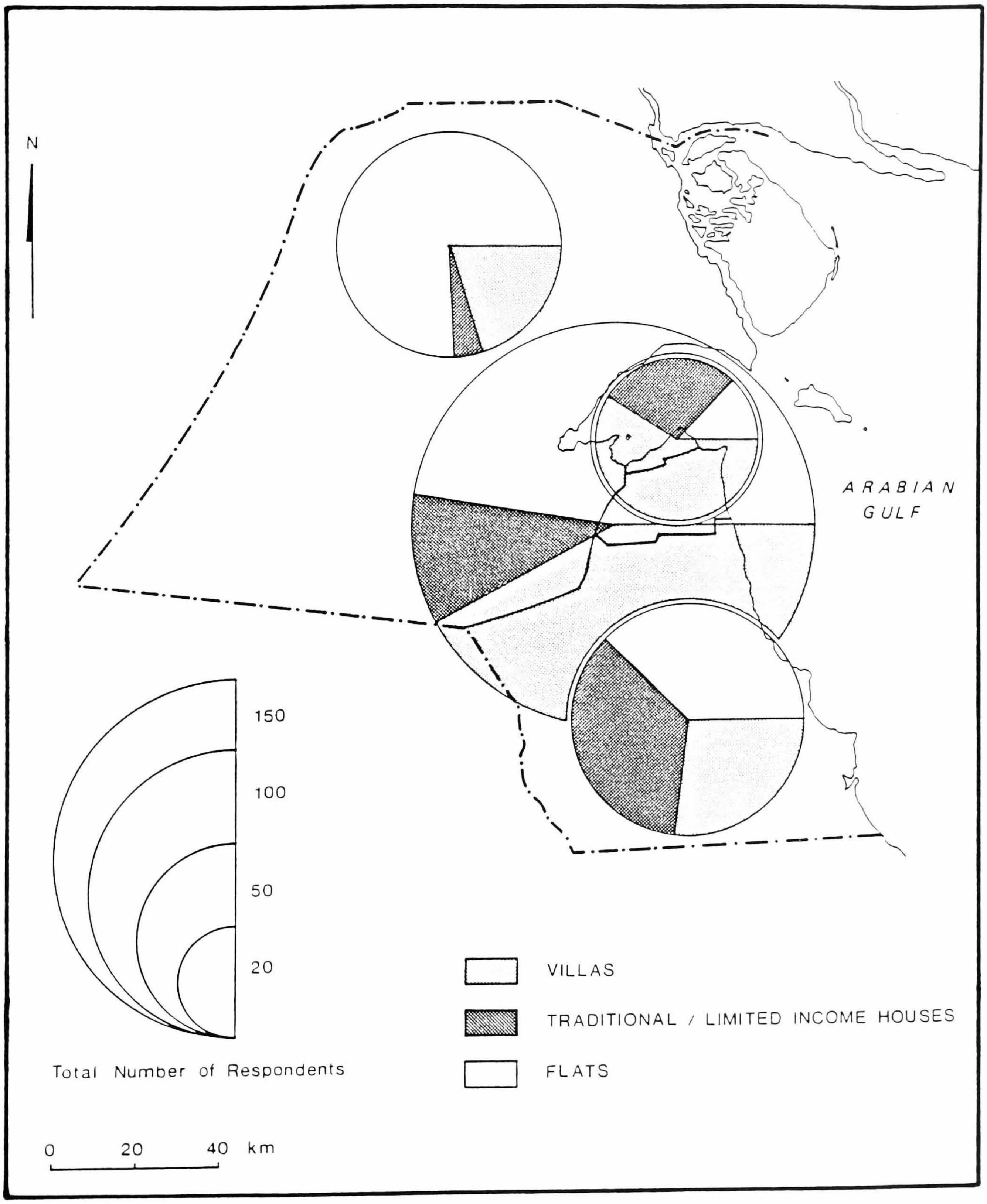

Figure 3: Distribution of respondents house type by governorates in Kuwait.

Part Two: Dust effects on Vehicles

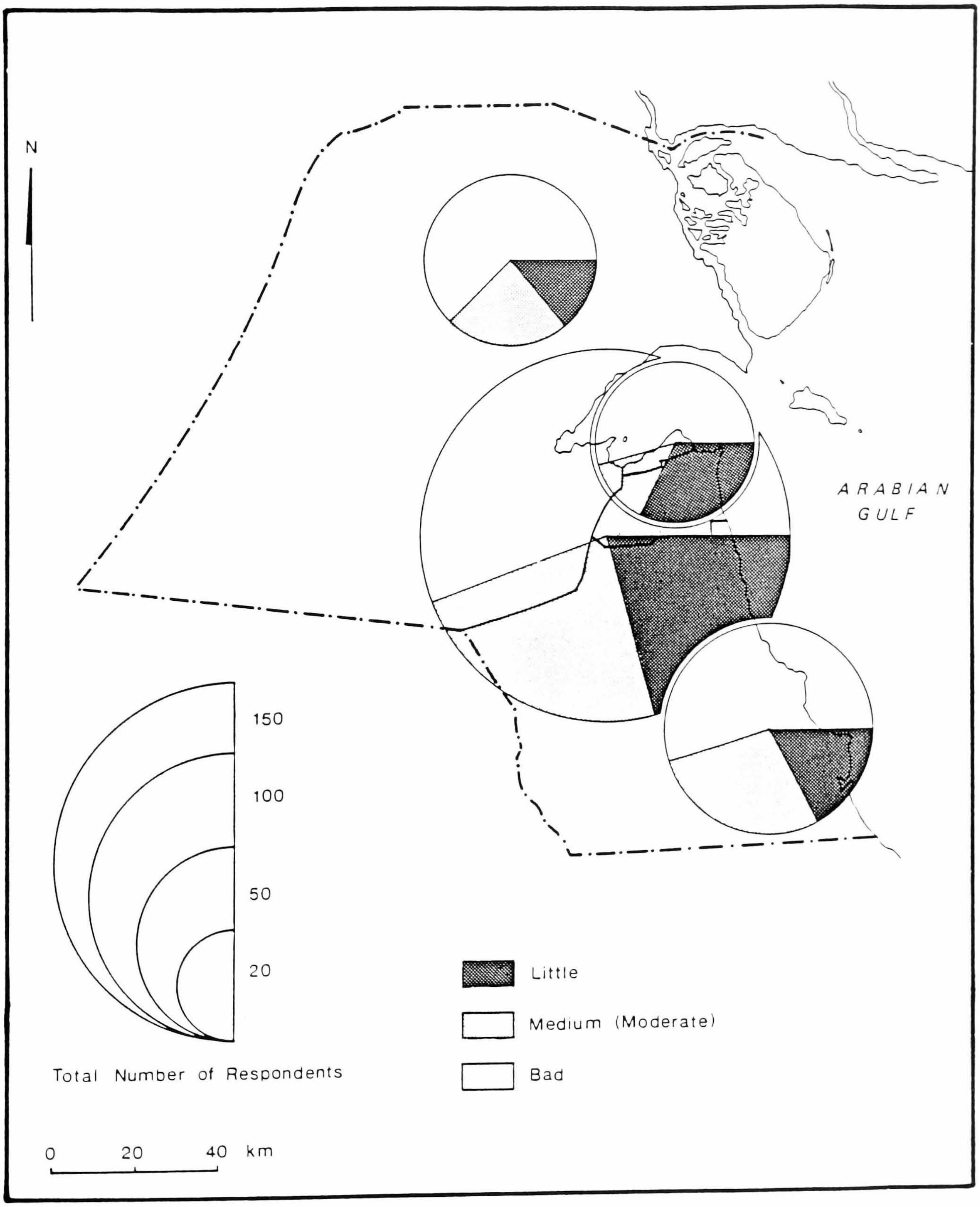

Figure 4: Distribution of respondents reaction to the effects of dust on car's windscreen by governorates in Kuwait.

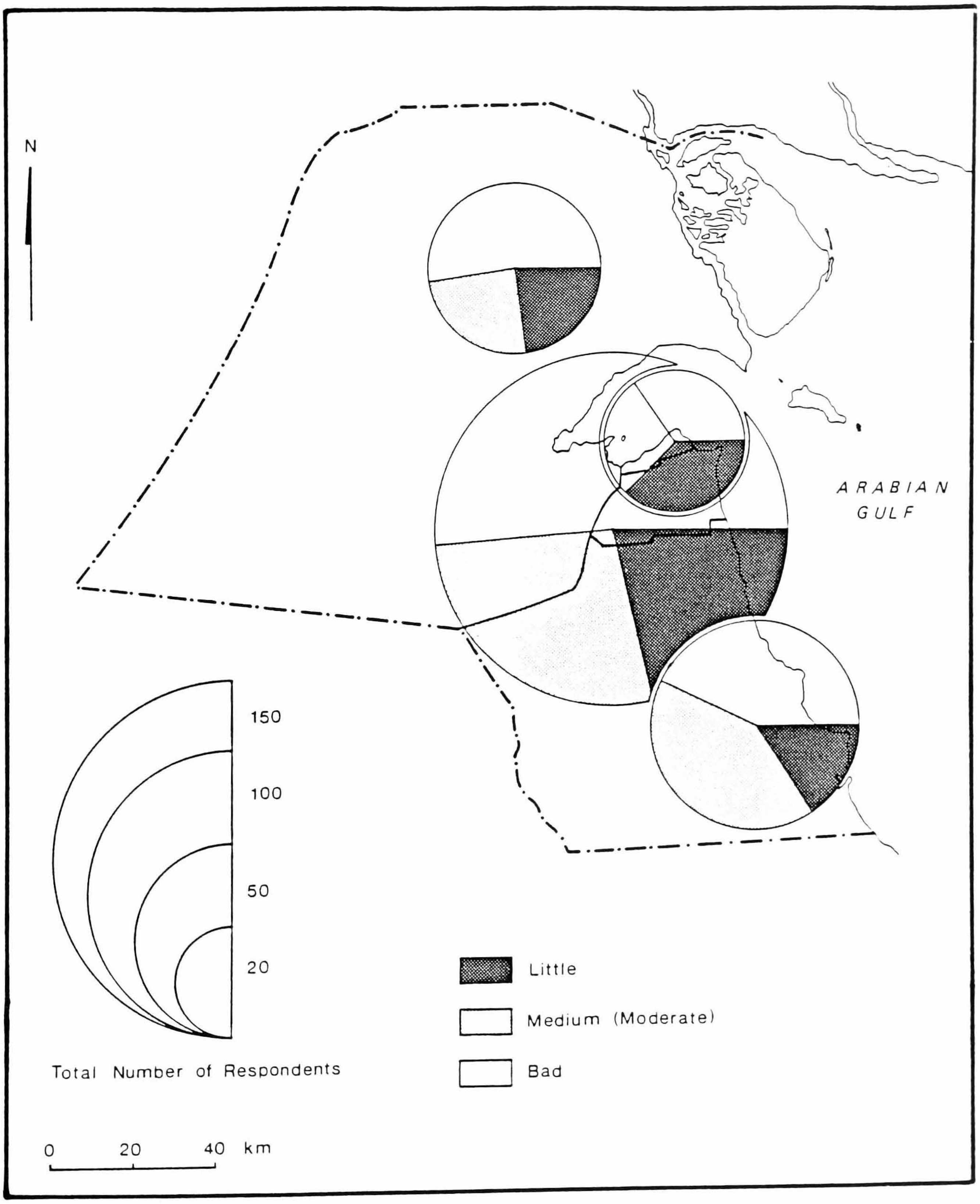

Figure 5: Distribution of respondents reaction to the effects of dust on car's front lights by governorates in Kuwait.

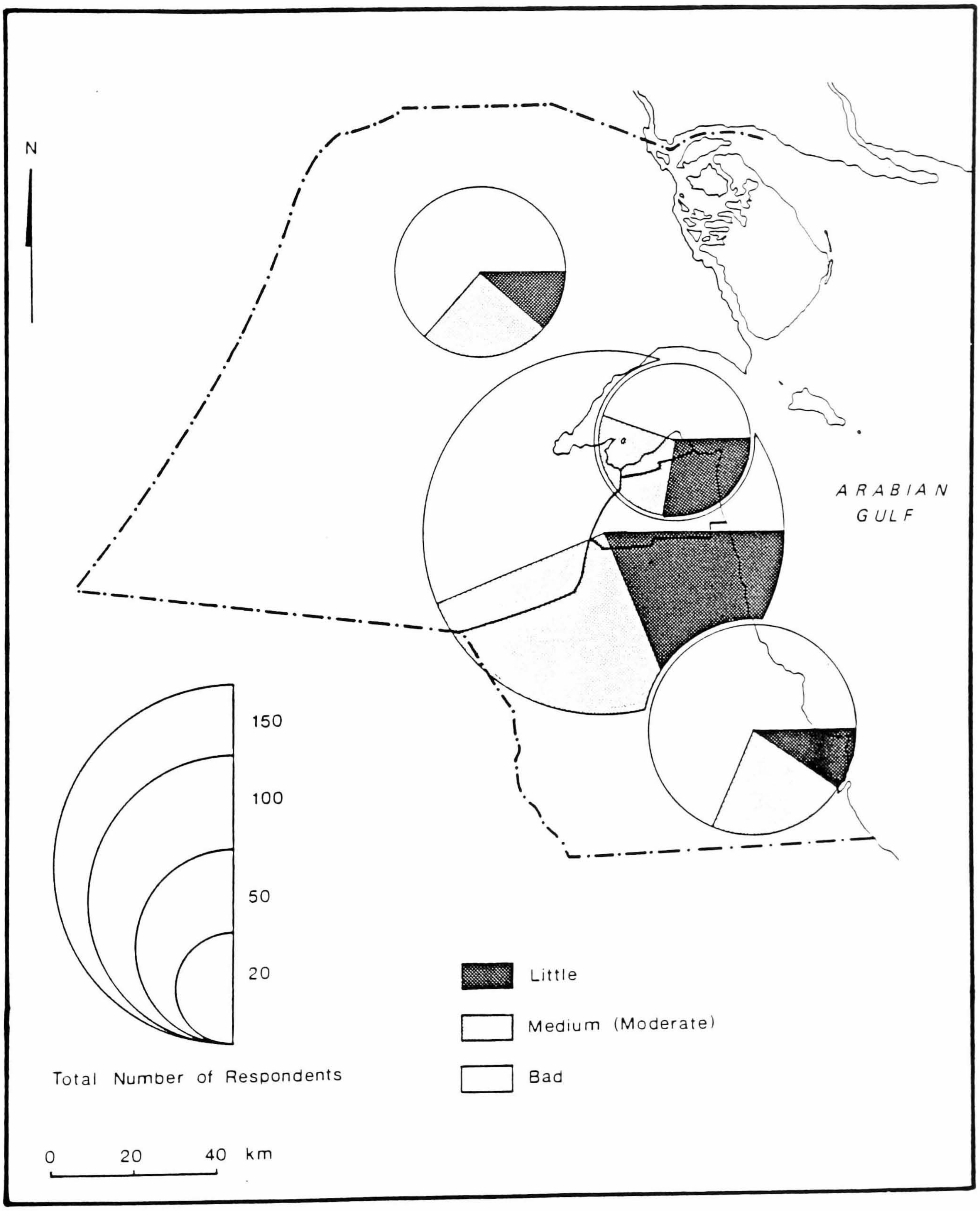

Figure 6: Distribution of respondents reaction to the effects s of dust on car's front paintwork by governorates in Kuwait.

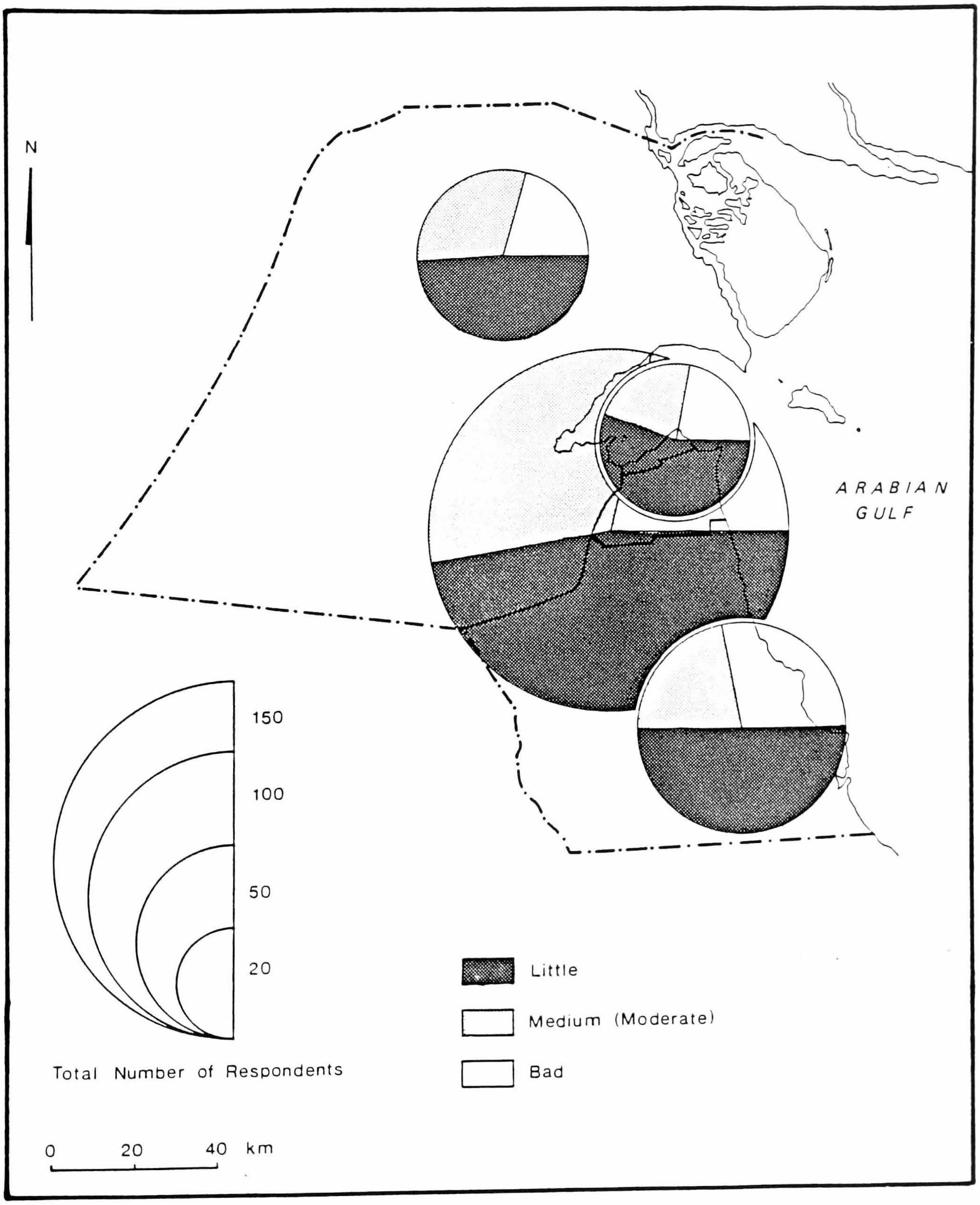

Figure 7: Distribution of respondents reaction to the effects s of dust on car's rear window by governorates in Kuwait.

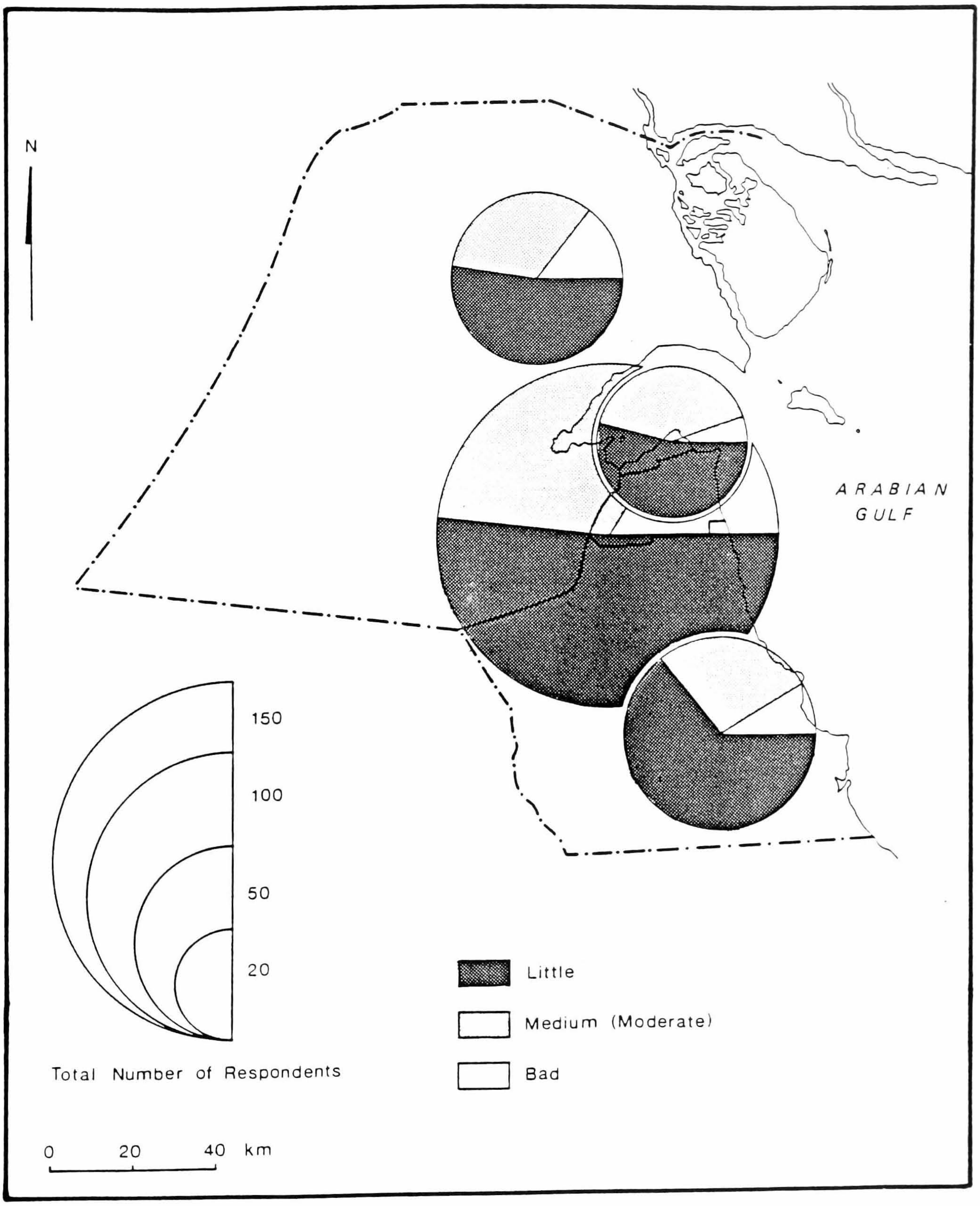

Figure 8: Distribution of respondents reaction of the effects of dust on car's rear lights by governorates in Kuwait.

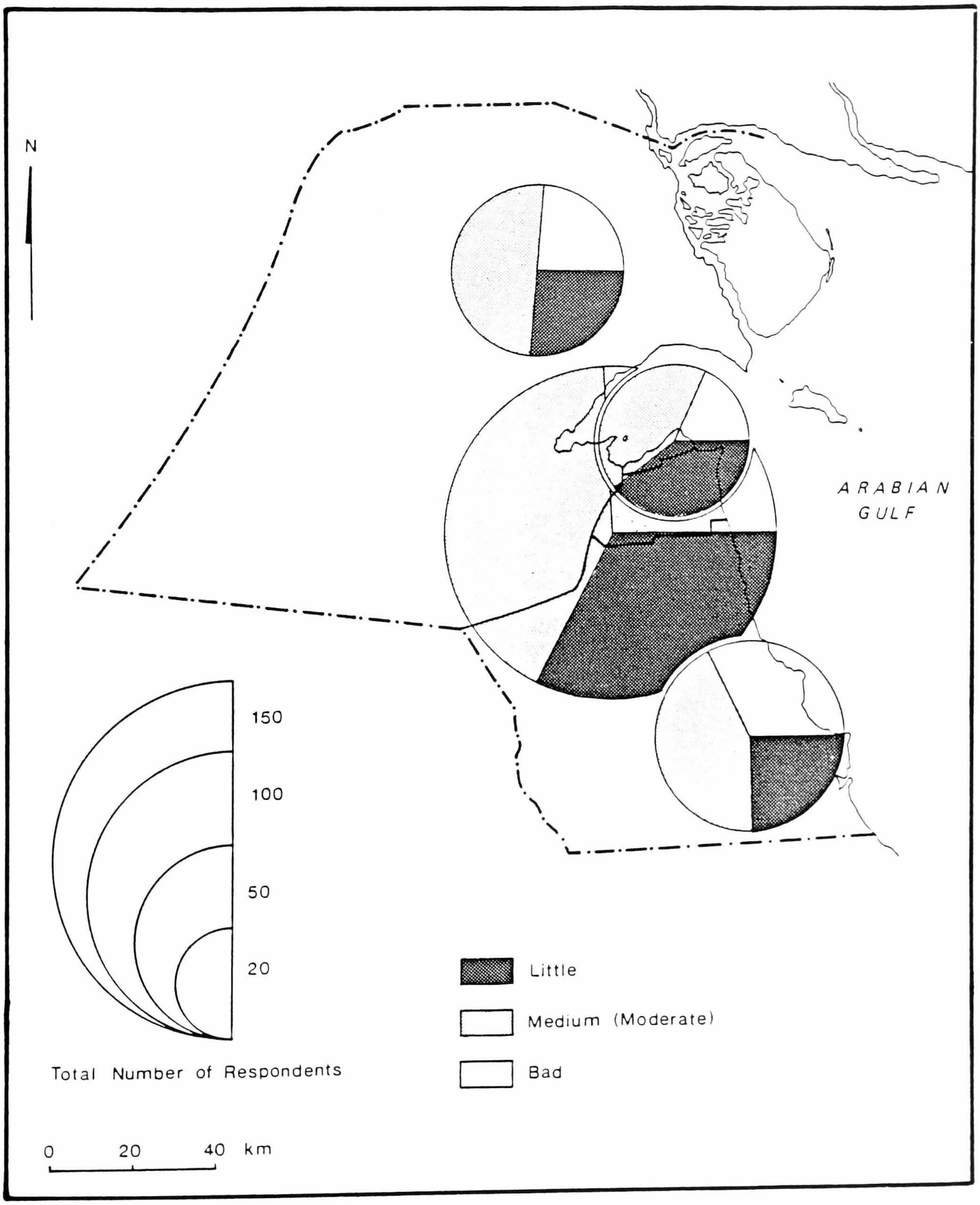

Figure 9: Distribution of respondents reaction to the effects of dust on car's engine by governorates in Kuwait.

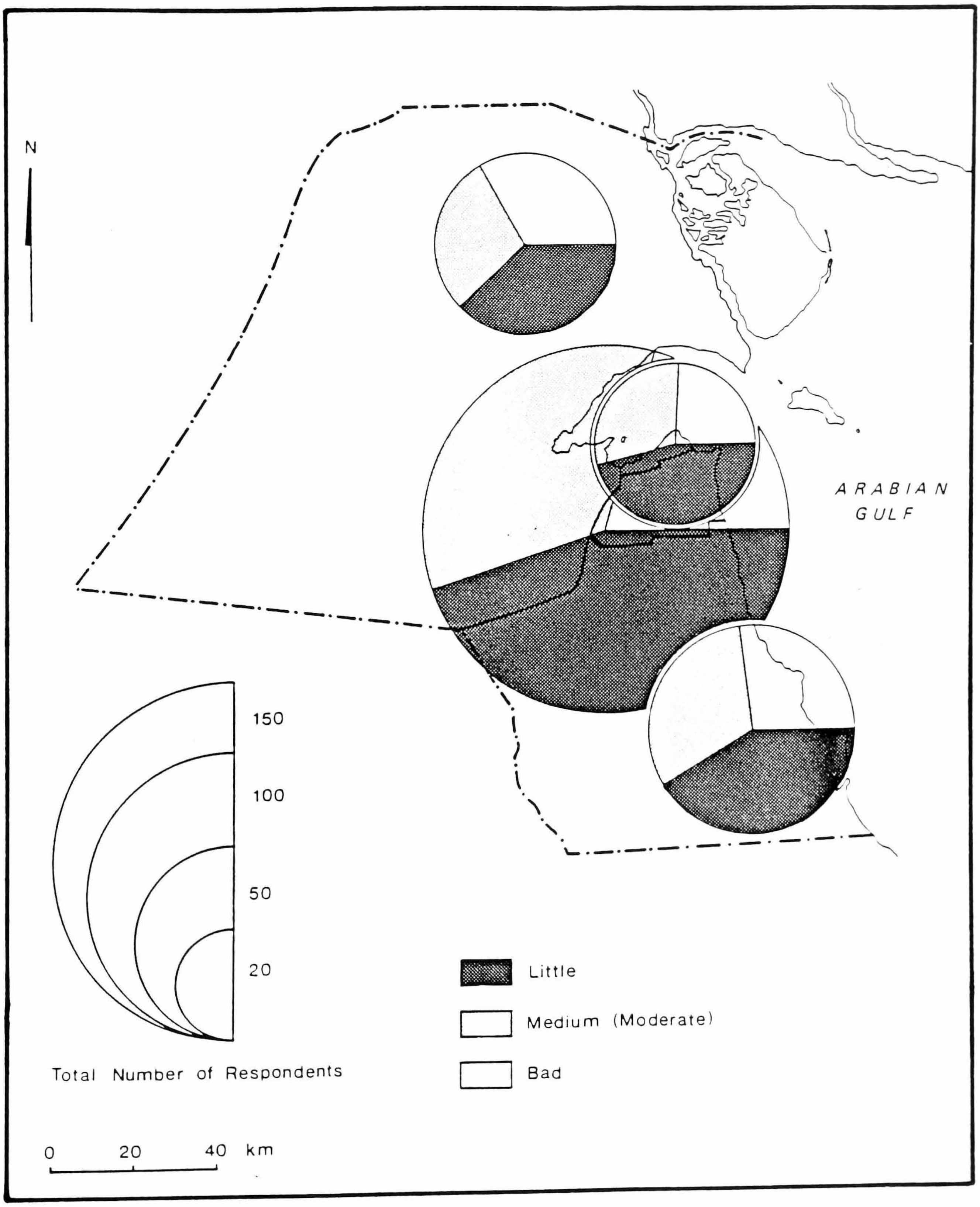

Figure 10: Distribution of respondents reaction the effects of dust on car's seats by governorates in Kuwait.

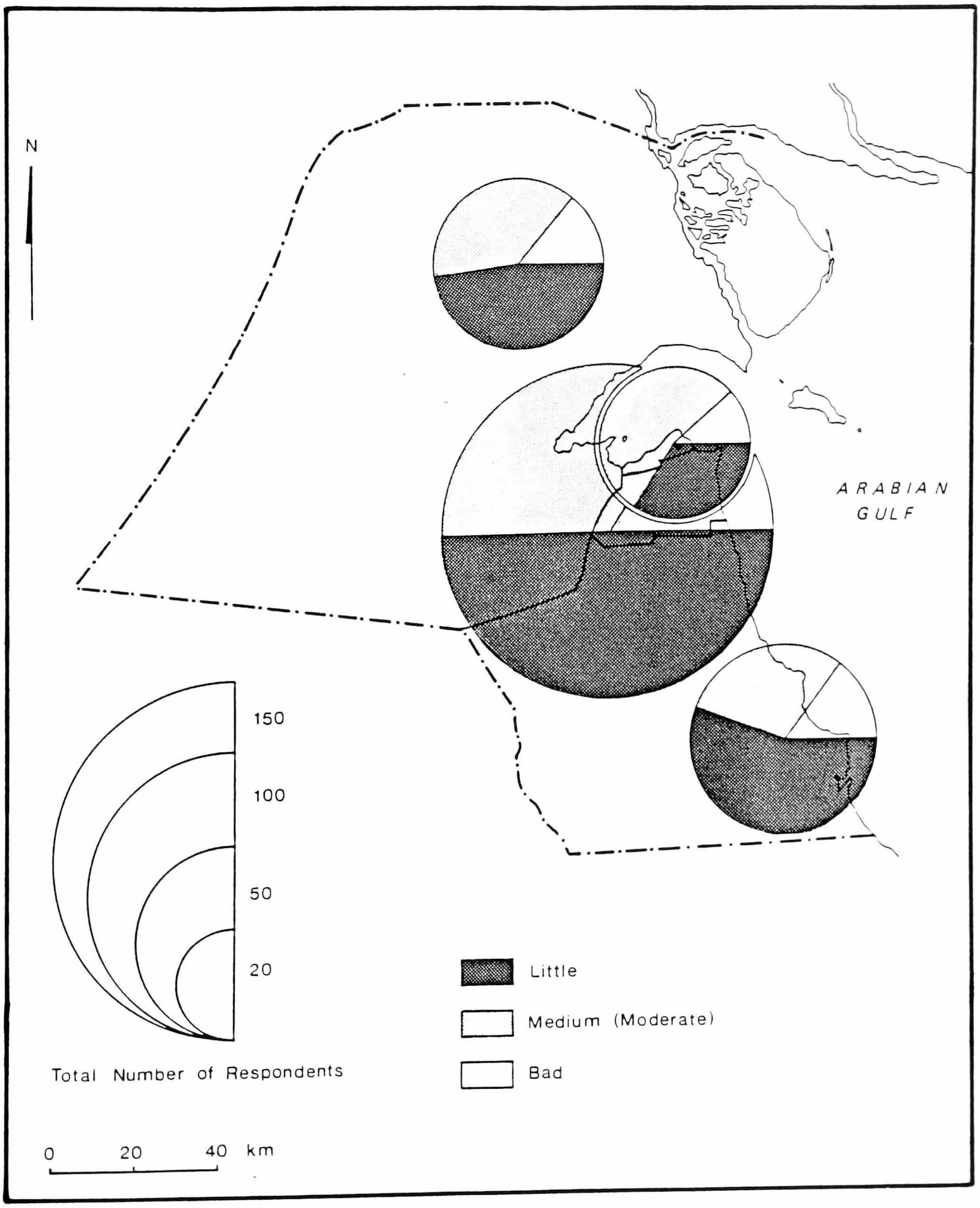

Figure 11: Distribution of reaction to the effects of dust on car's gauges by governorates in Kuwait.

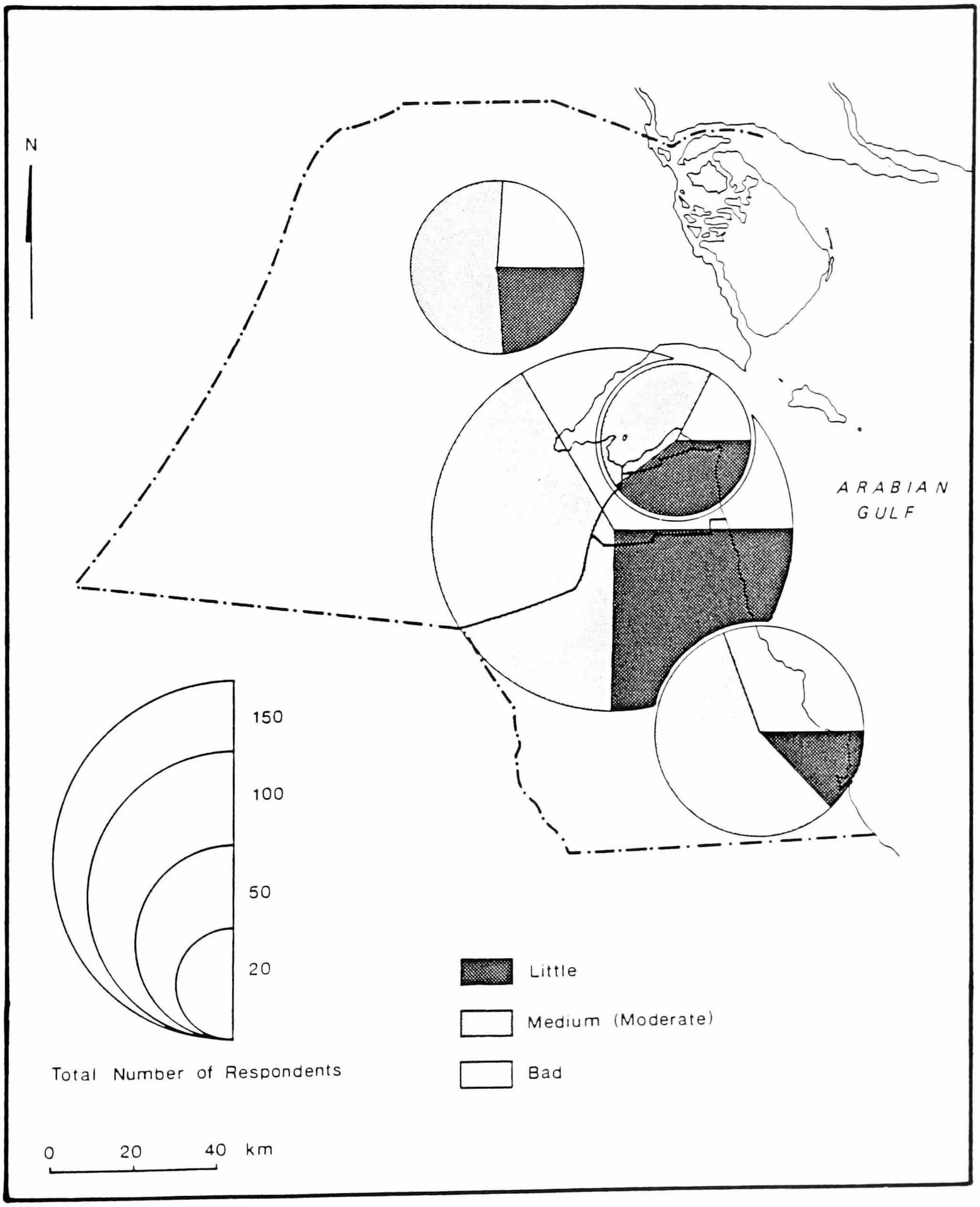

Figure 12: Distribution of respondents reaction to the effects of dust on car's paintwork generally by governorates in Kuwait.

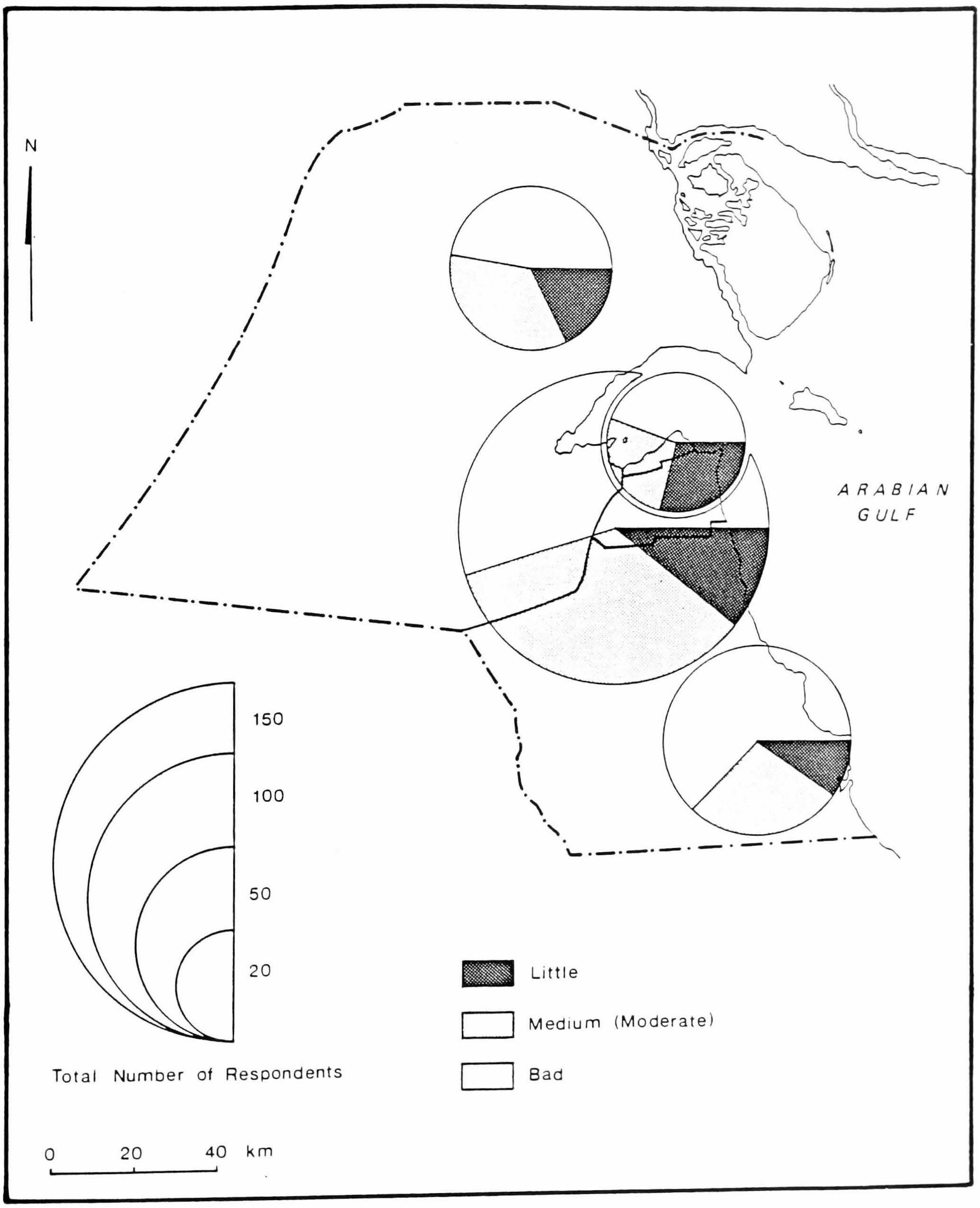

Figure 13: Distribution of respondents reaction to the effects of dust on car's engine air filter by governorates in Kuwait.

Part Three: Dust Effects on Buildings

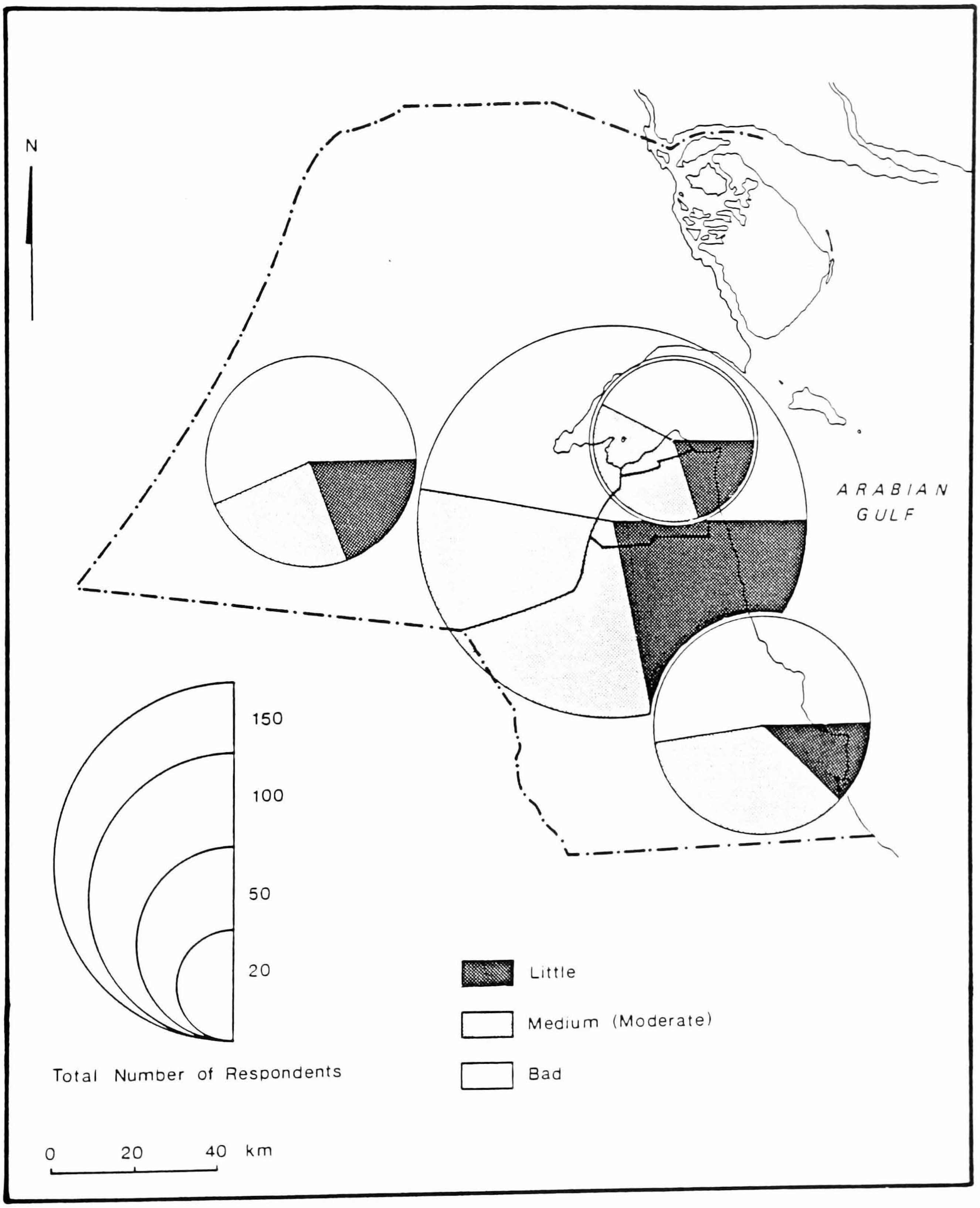

Figure 14: Distribution of reaction to the the effects of dust on out-side house windows by governorates in Kuwait.

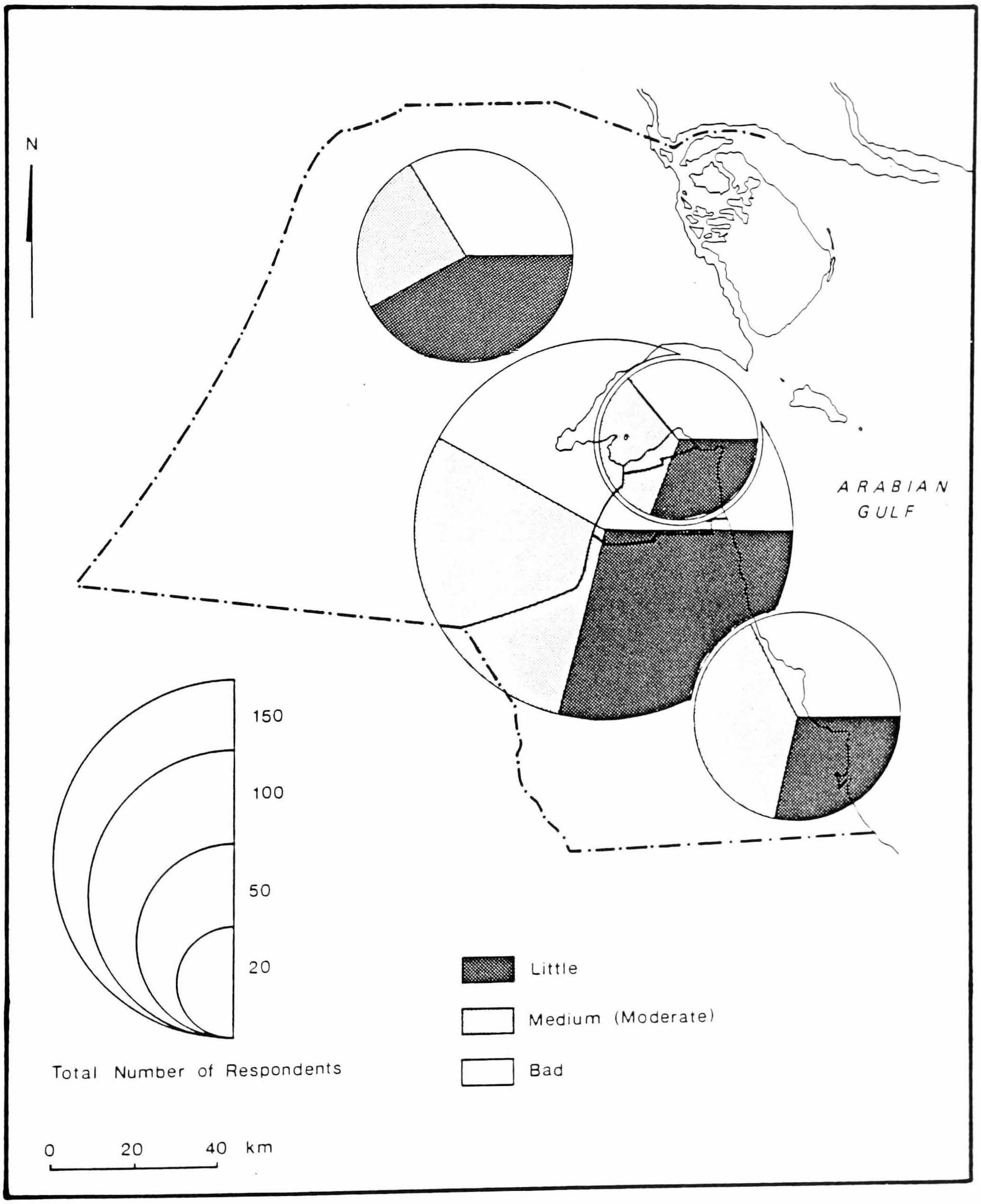

Figure 15: Distribution of respondents reaction to the effects of dust on the out-side paint of house by governorates in Kuwait.

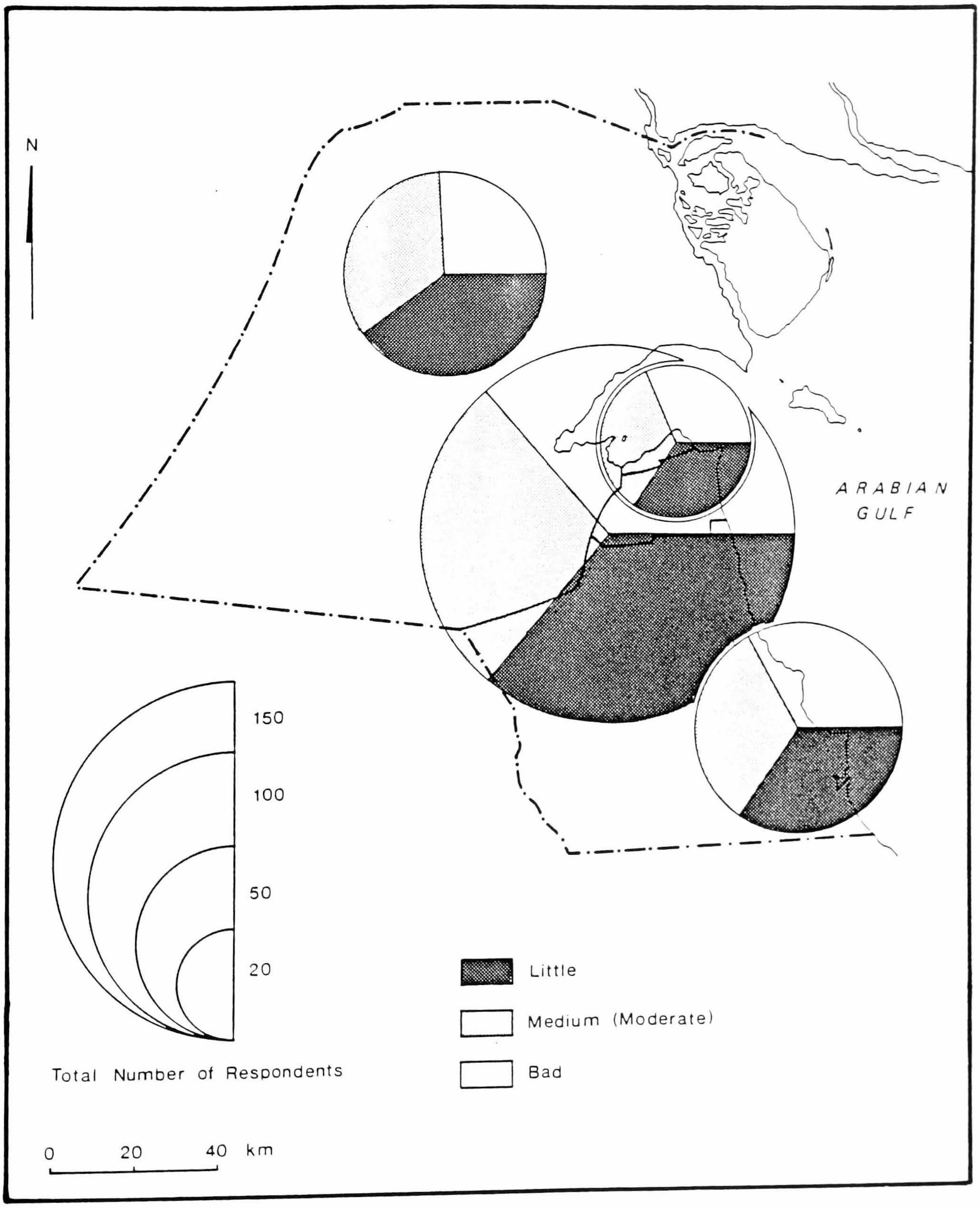

Figure 16: Distribution of respondents reaction to the effects of dust on the surface of out-side door by governorates in Kuwait.

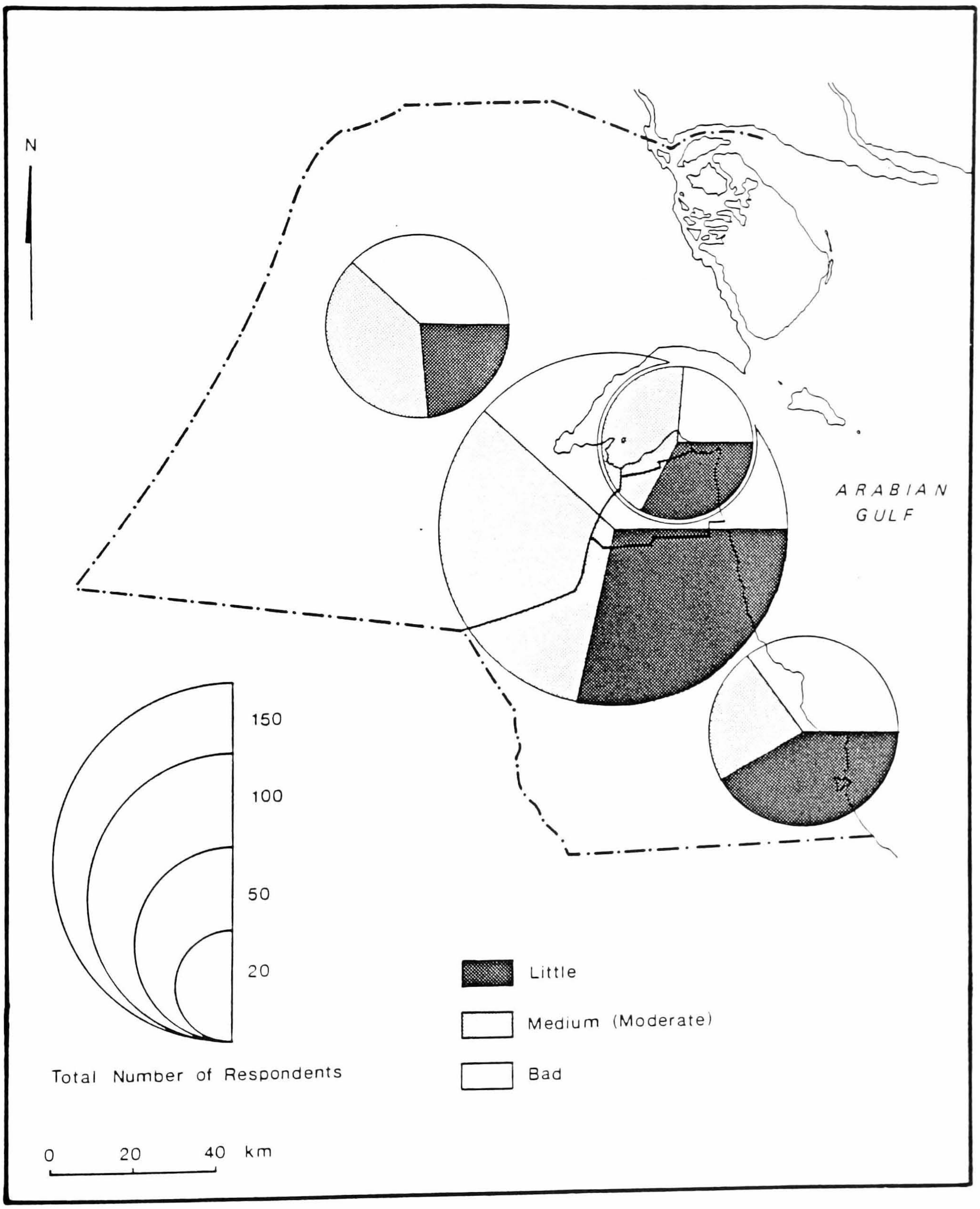

Figure 17: Distribution of respondents reaction to the effects of dust on household water tankes by governorates in Kuwait.

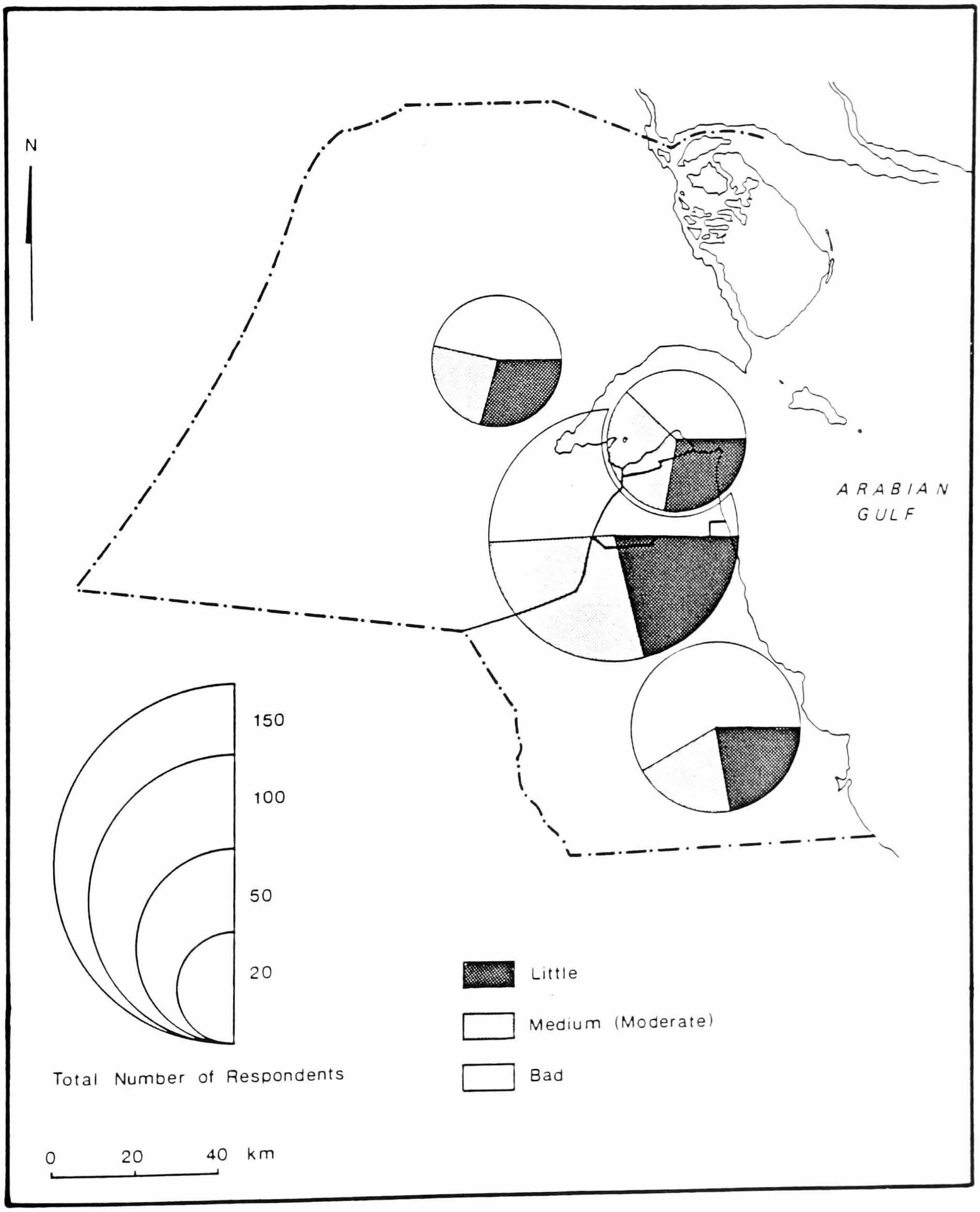

Figure 18: Distribution of respondents reaction to the effects of dust on household gardens by governorates in Kuwait.

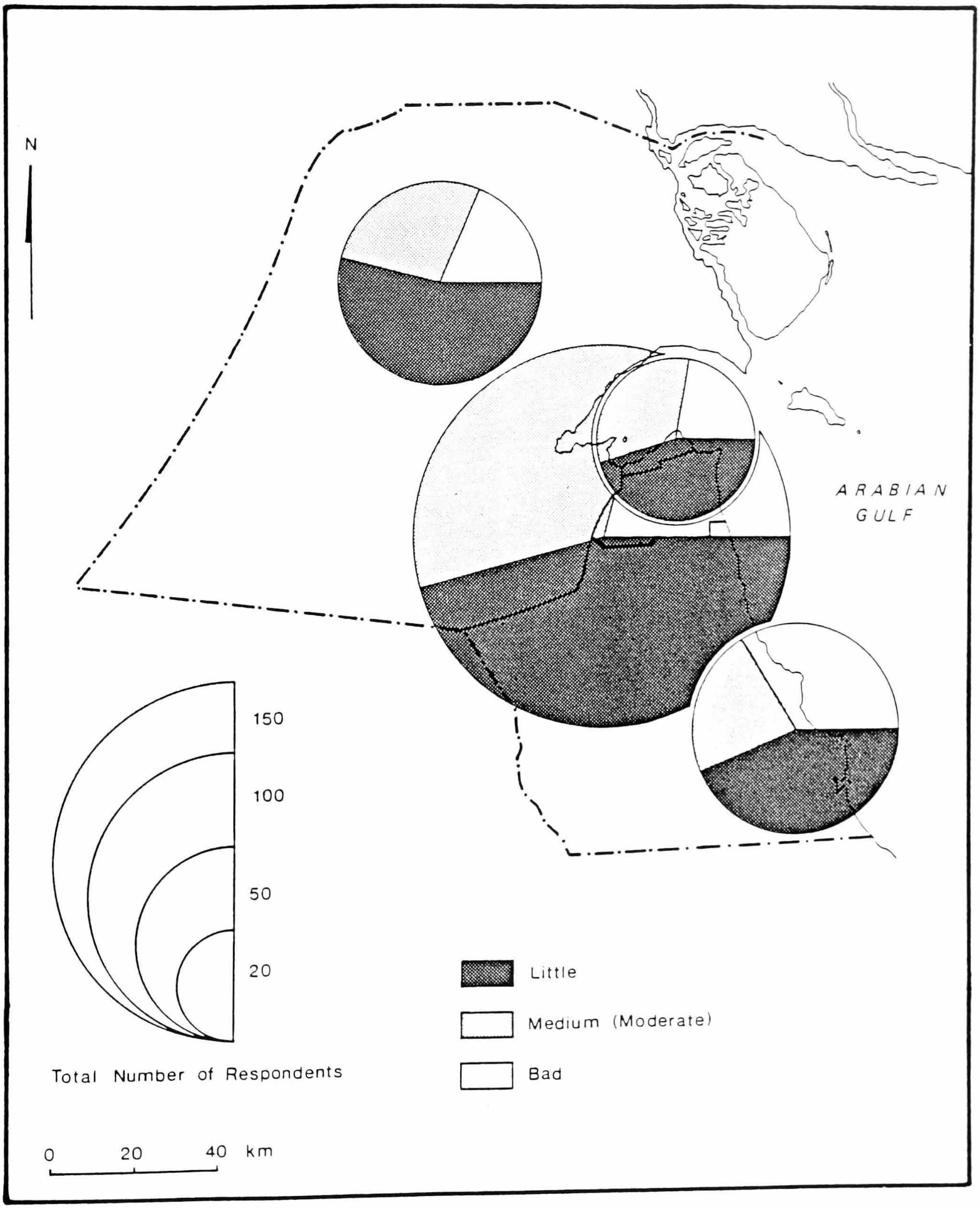

Figure 19: Distribution of respondents reaction to the respondents to the effects of dust on household electrical equipments by governorates in Kuwait.

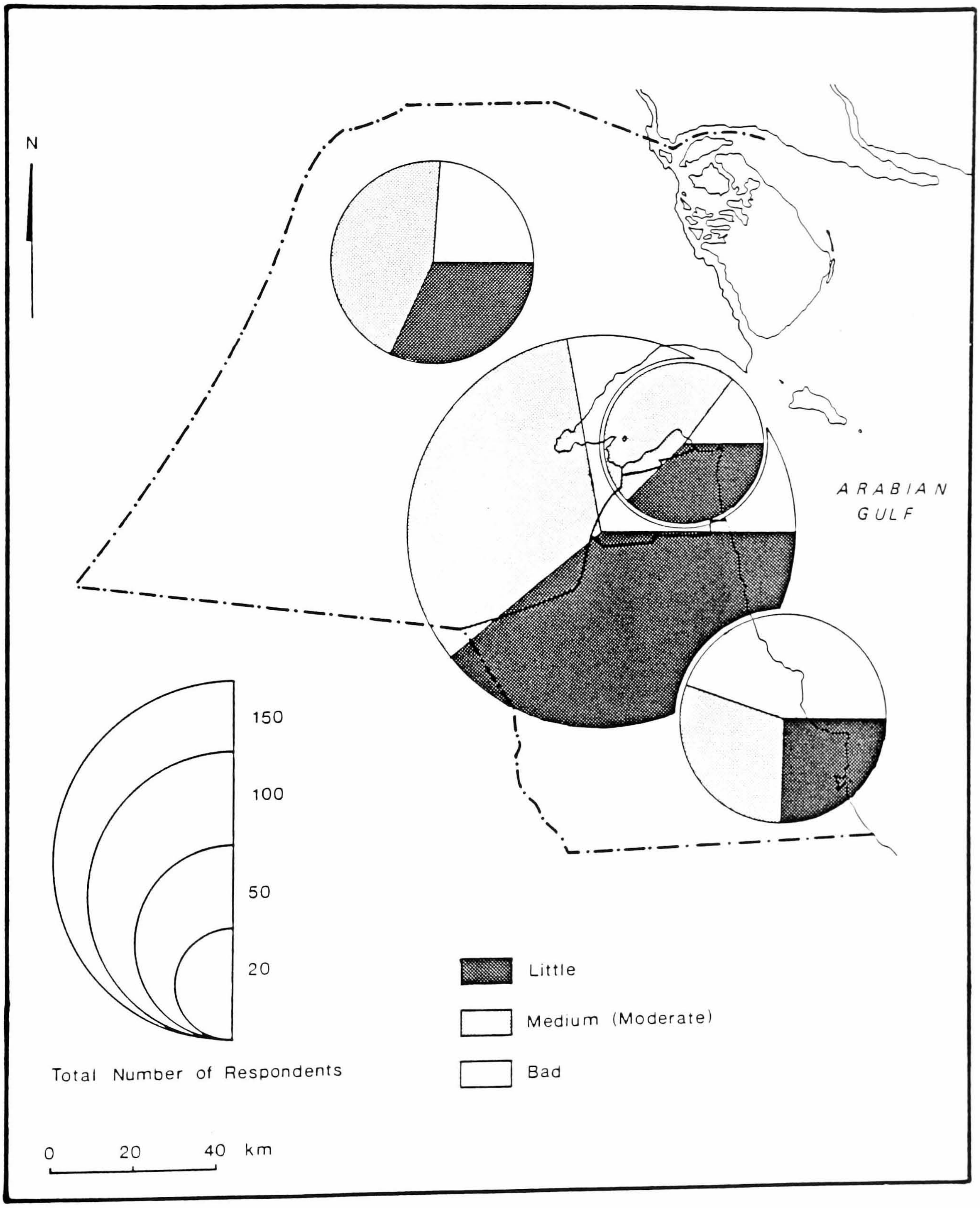

Figure 20: Distribution of respondents reaction to the effects of dust on household carpets by governorates in Kuwait.

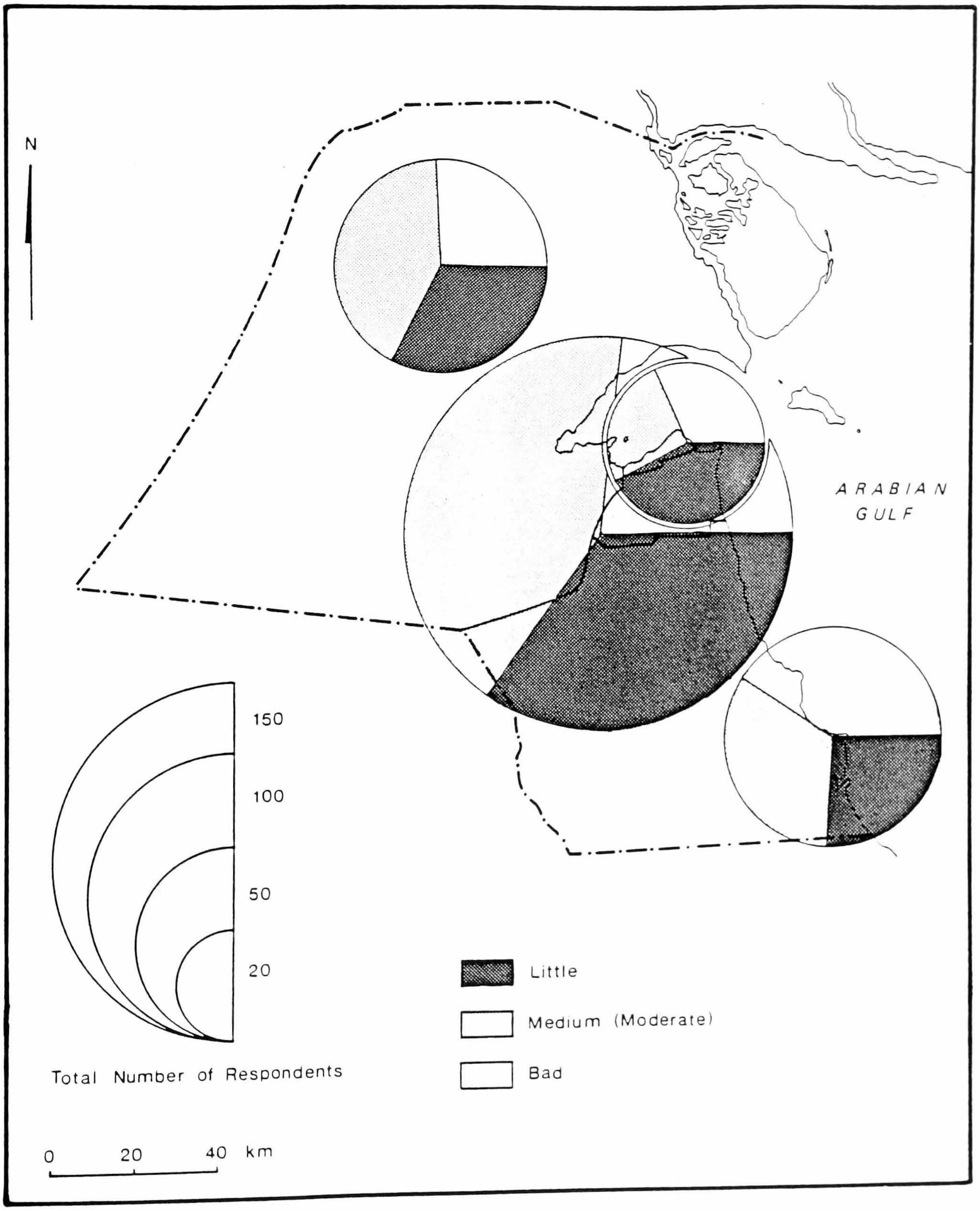

Figure 21: Distribution of respondents reaction to the effects of dust on household furniture by governorates in Kuwait.

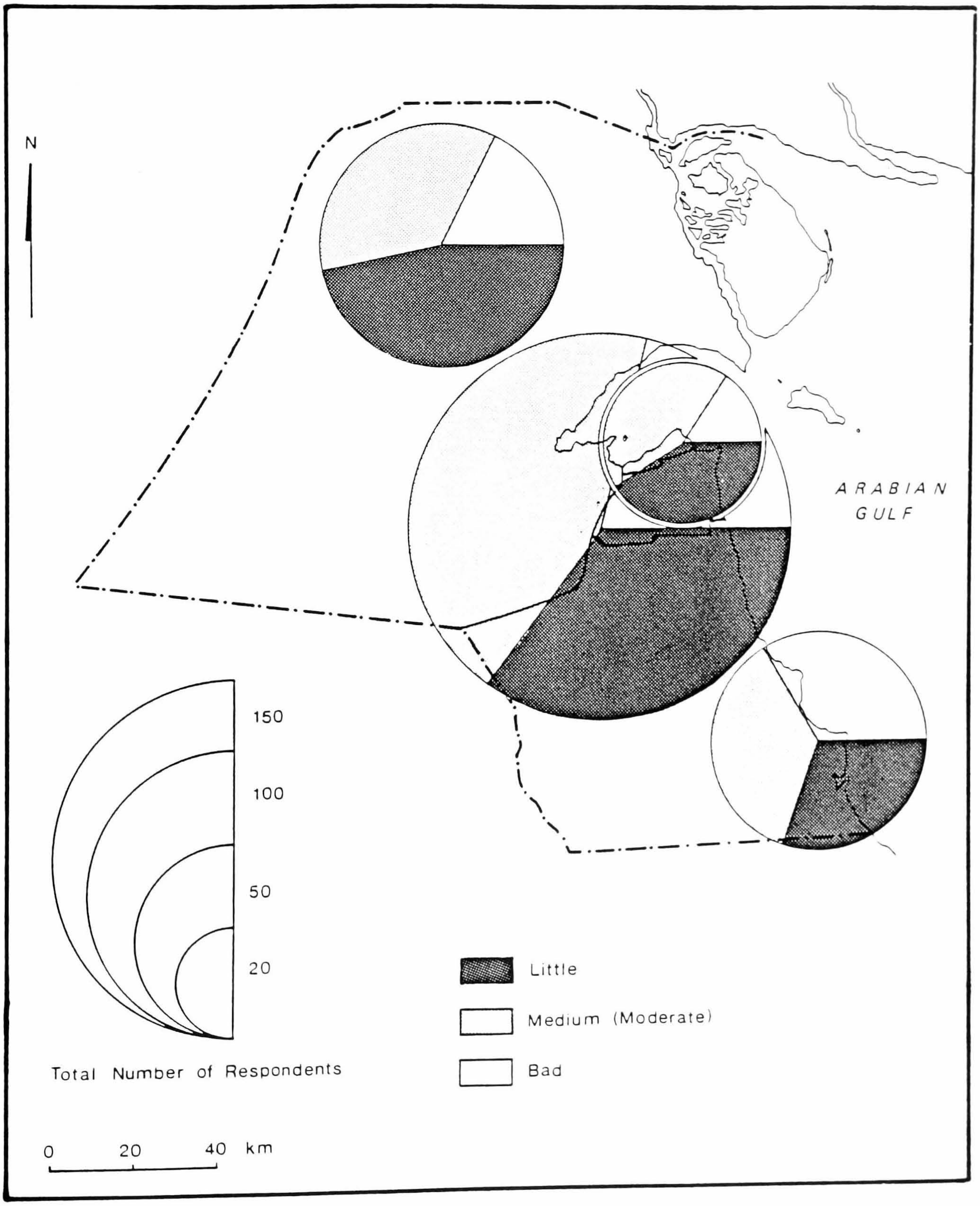

Figure 22: Distribution of respondents reaction to the effects of dust on living rooms by governorates in Kuwait.

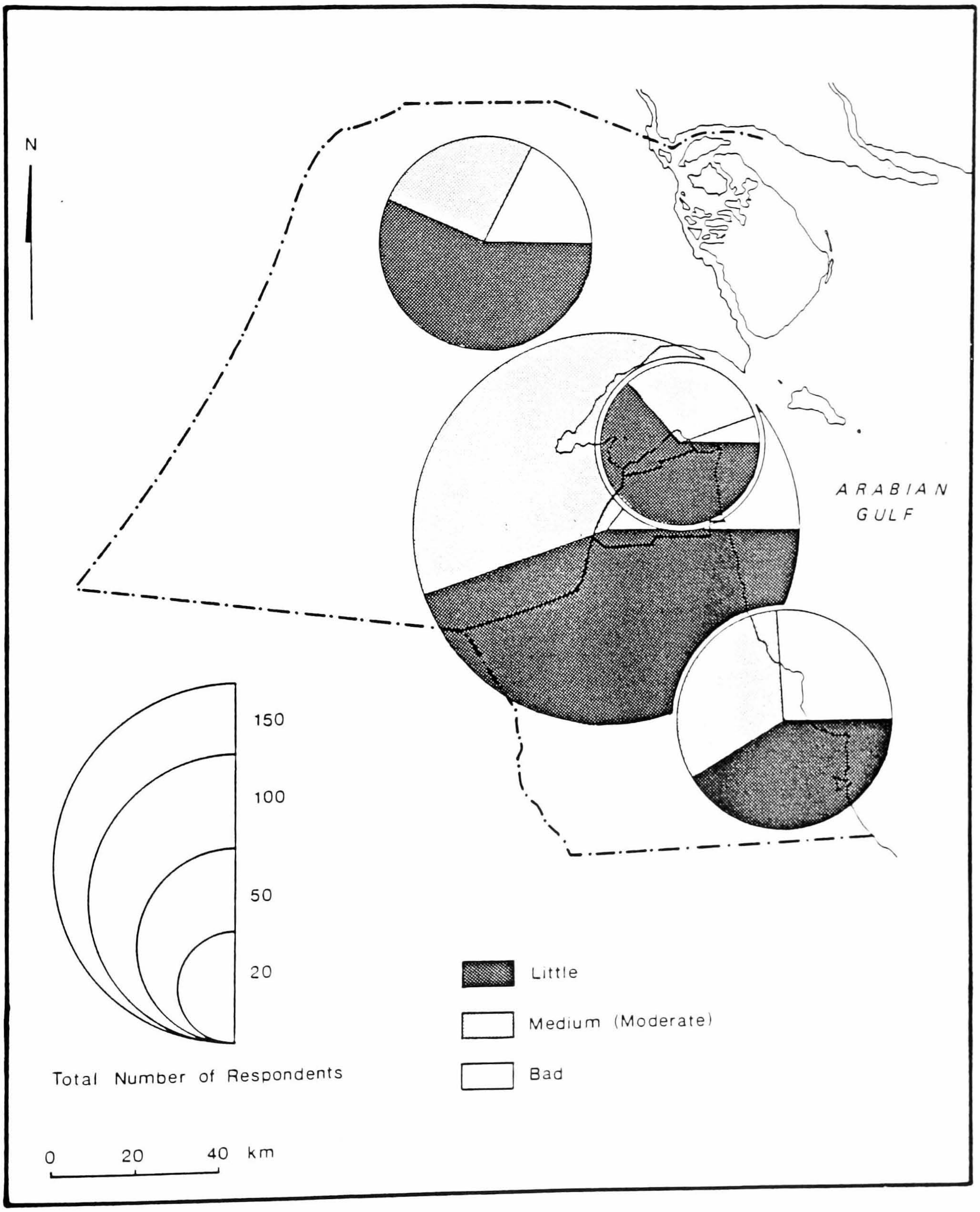

Figure 23: Distribution of respondents reaction to the effects of dust on bed rooms by governorates in Kuwait.

Part Four: Dust Effects on People's Health

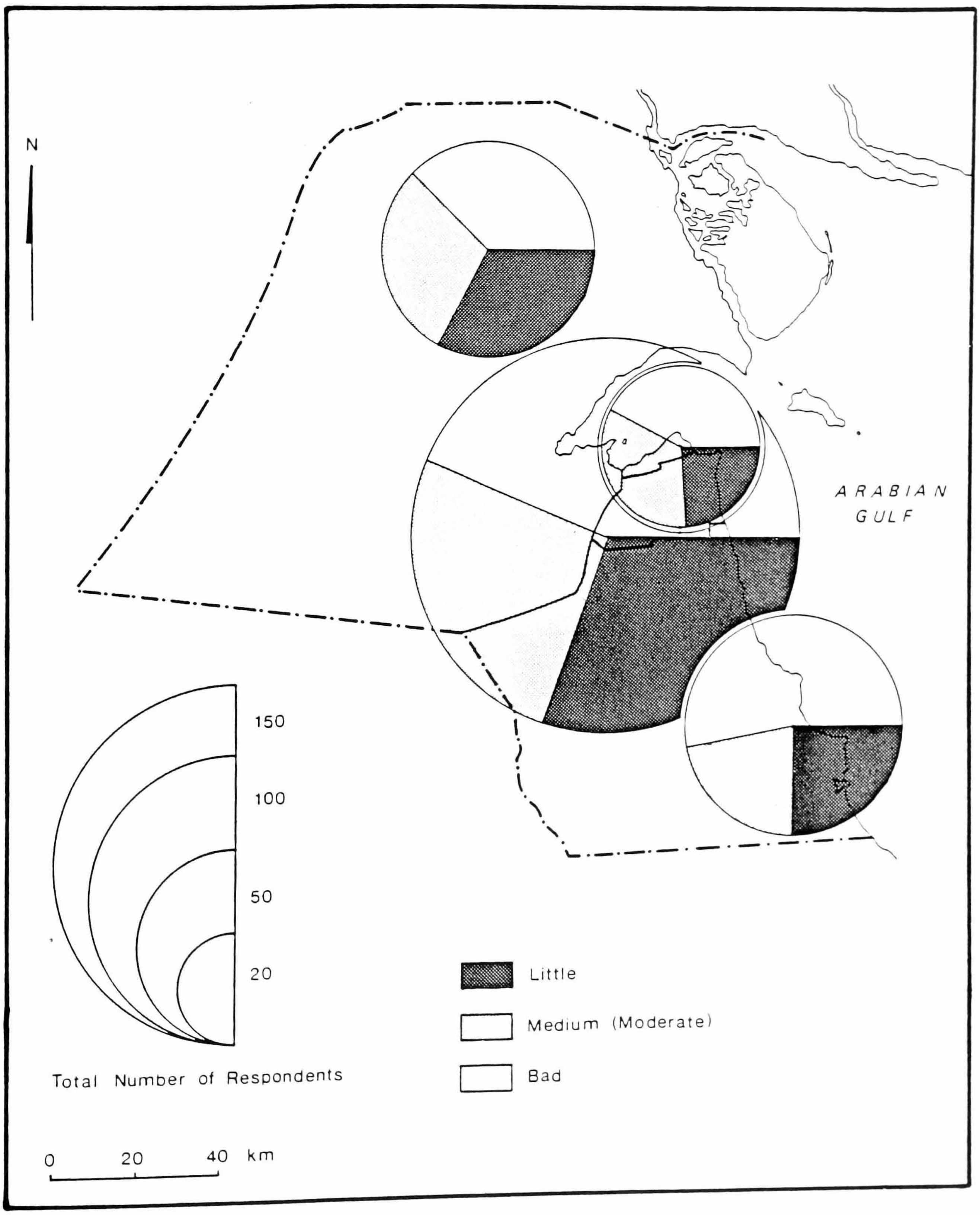

Figure 24: Distribution of respondents reaction to the effects of dust on the eyes by governorates in Kuwait.

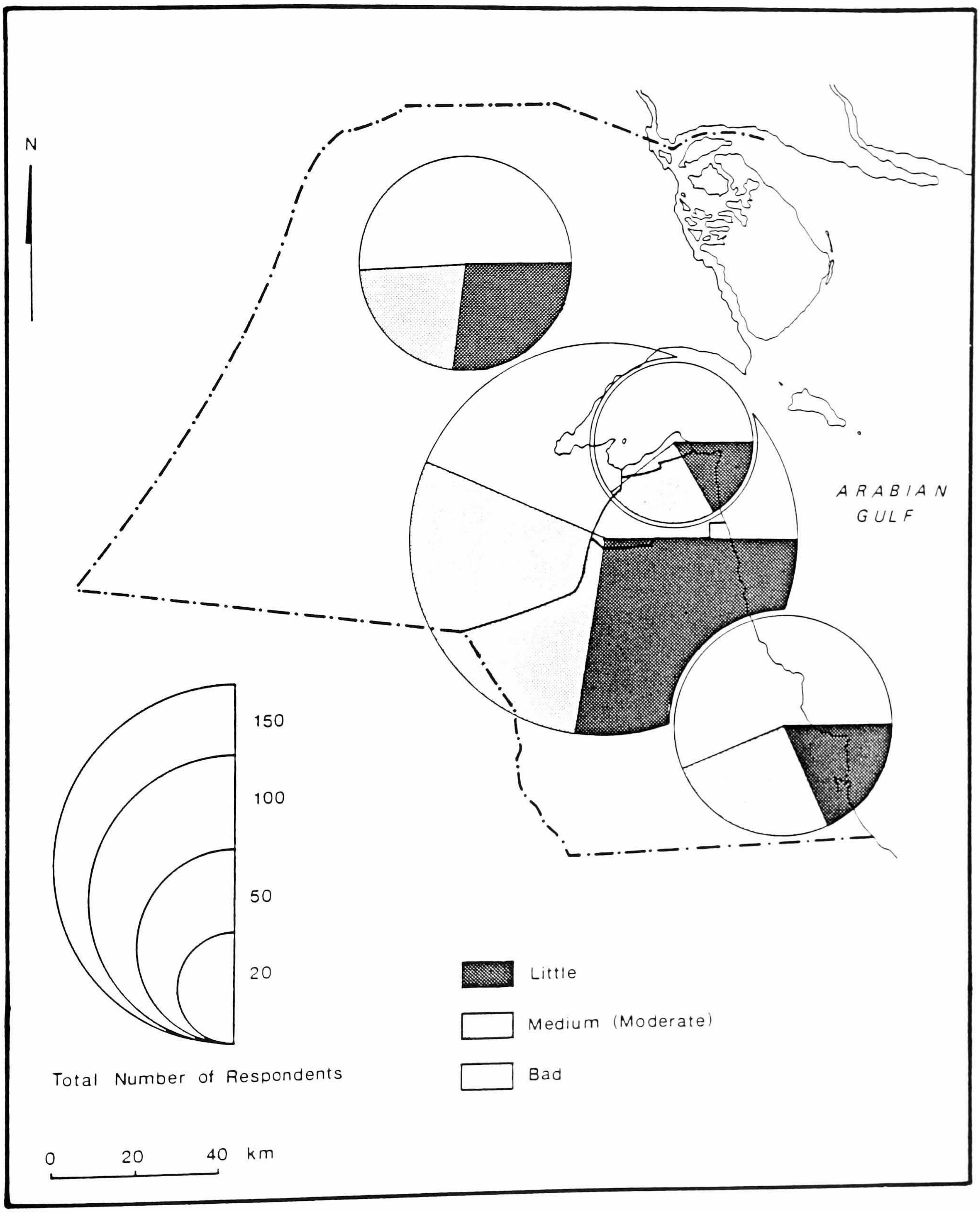

Figure 25: Distribution of respondents reaction to the effects of dust on the nose by governorates in Kuwait.

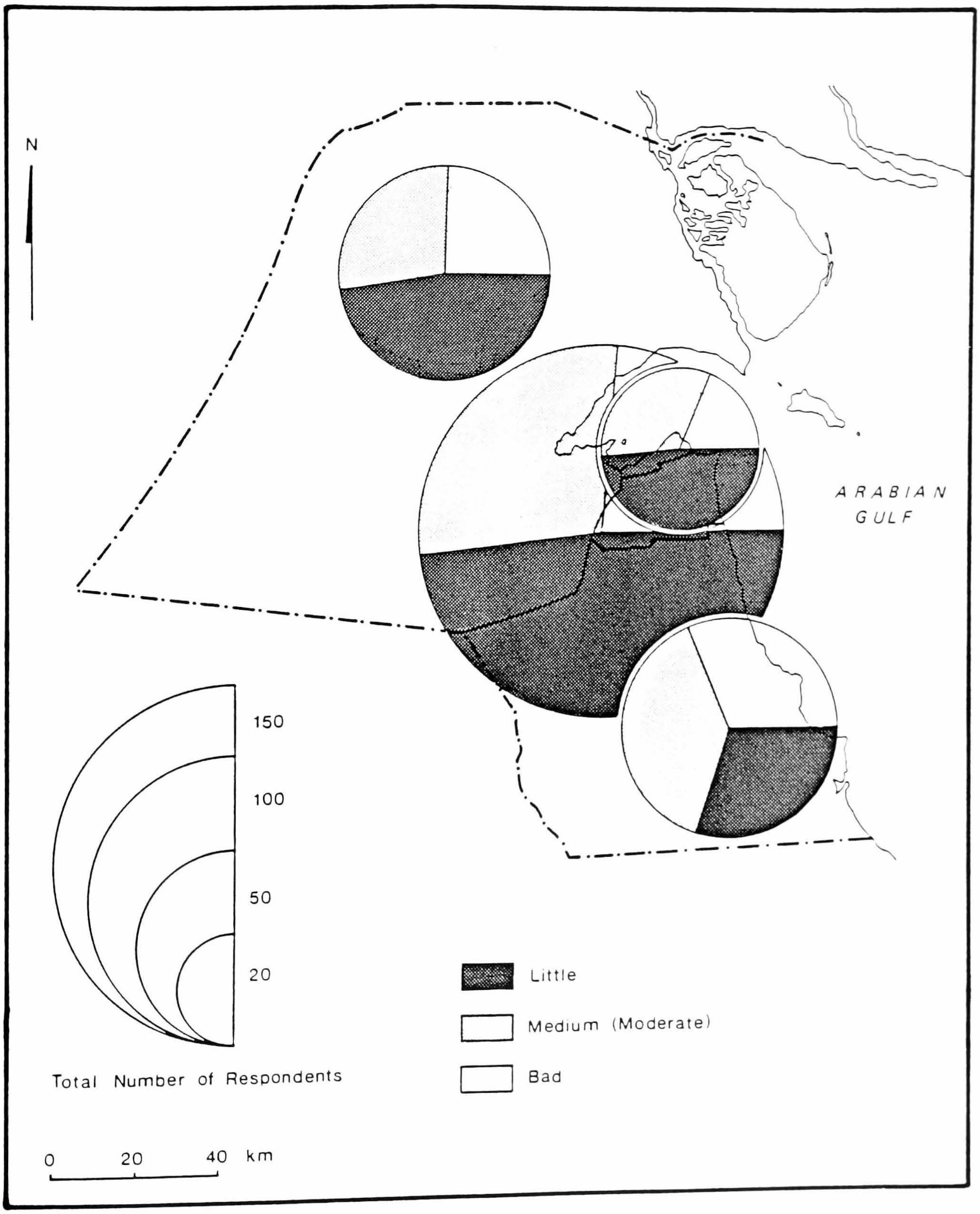

Figure 26: Distribution of respondents reaction to the effects of dust on the face by governorates in Kuwait.

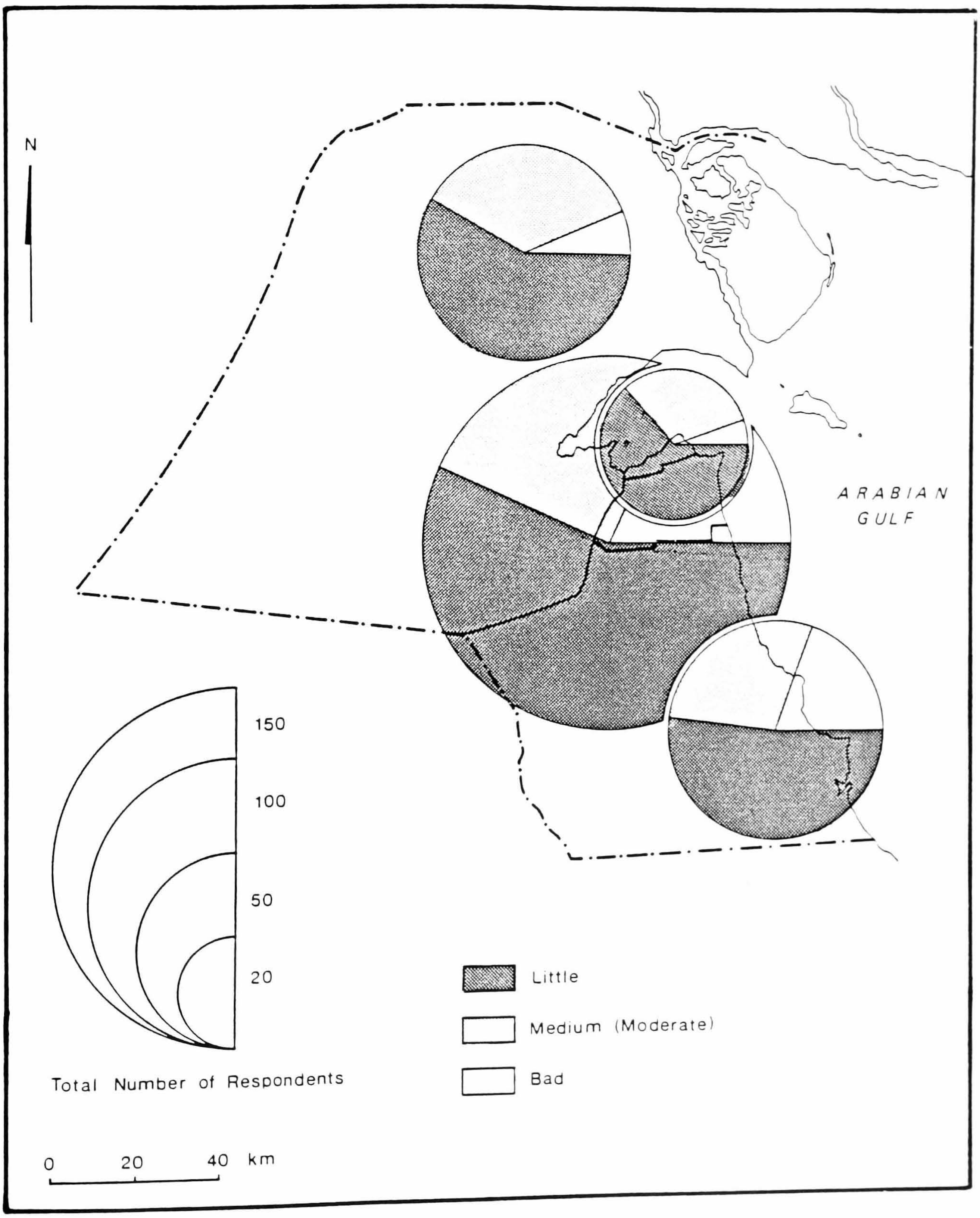

Figure 27: Distribution of respondents reaction to the effects of dust on the ears by governorates in Kuwait.

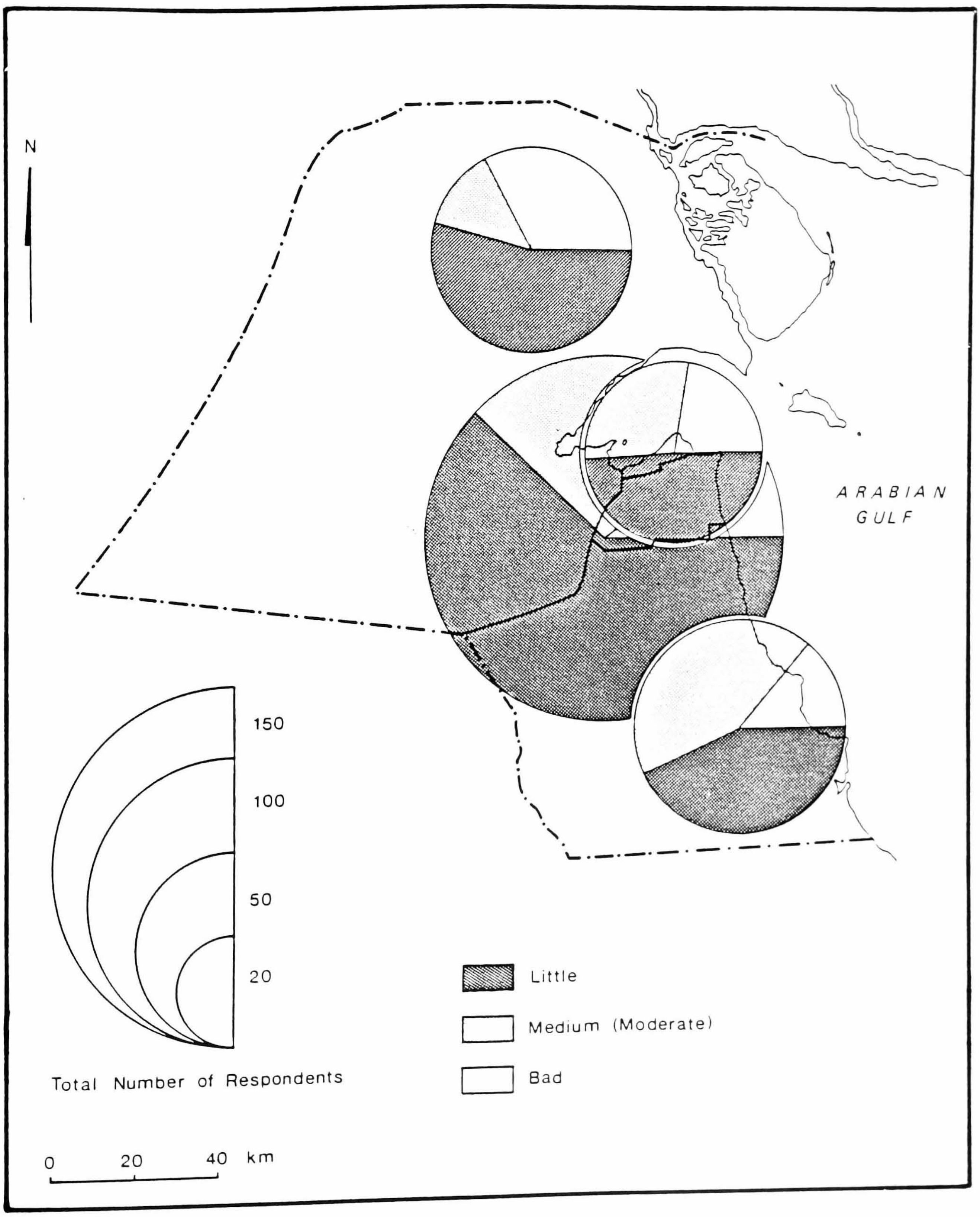

Figure 28: Distribution of respondents reaction to the effects of dust on the skin by governorates in Kuwait.

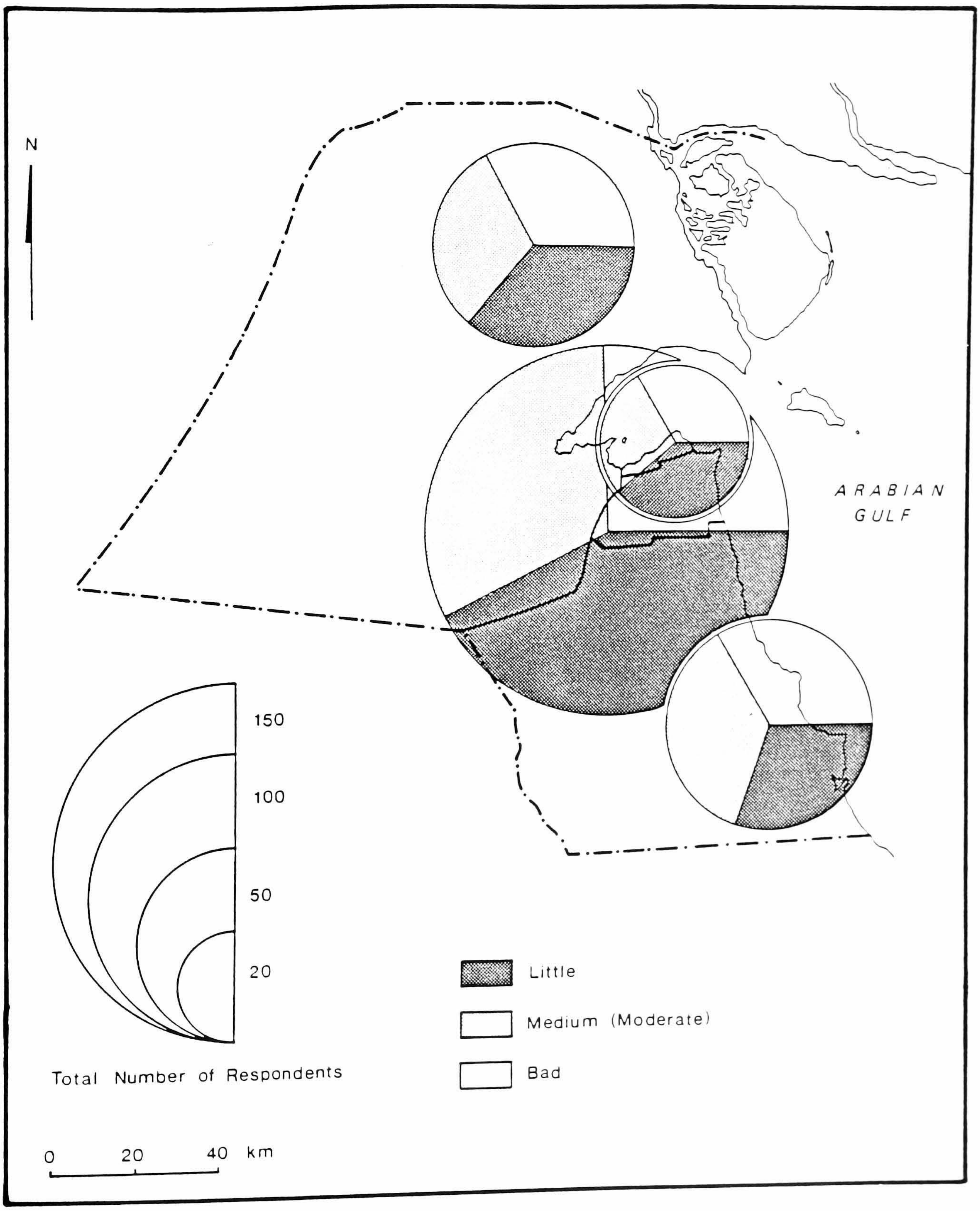

Figure 29: Distribution of respondents reaction to the effects of dust on throat by governorates in Kuwait.

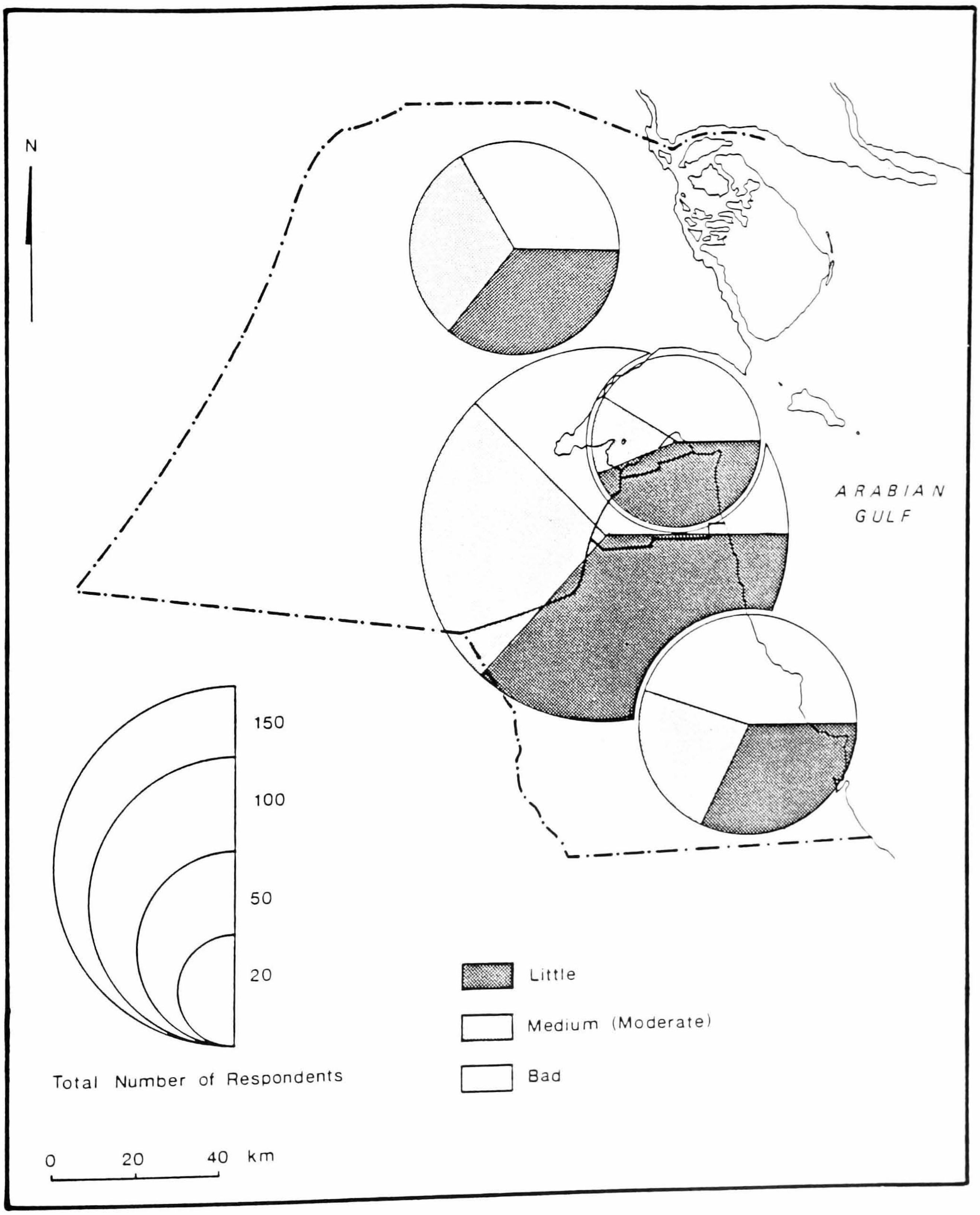

Figure 30: Distribution of respondents reaction to the effects of dust on the chest "breathing" by governorates in Kuwait.