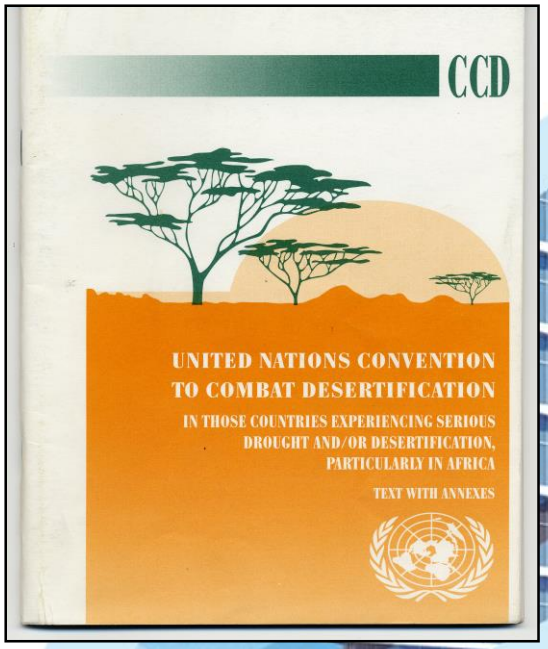
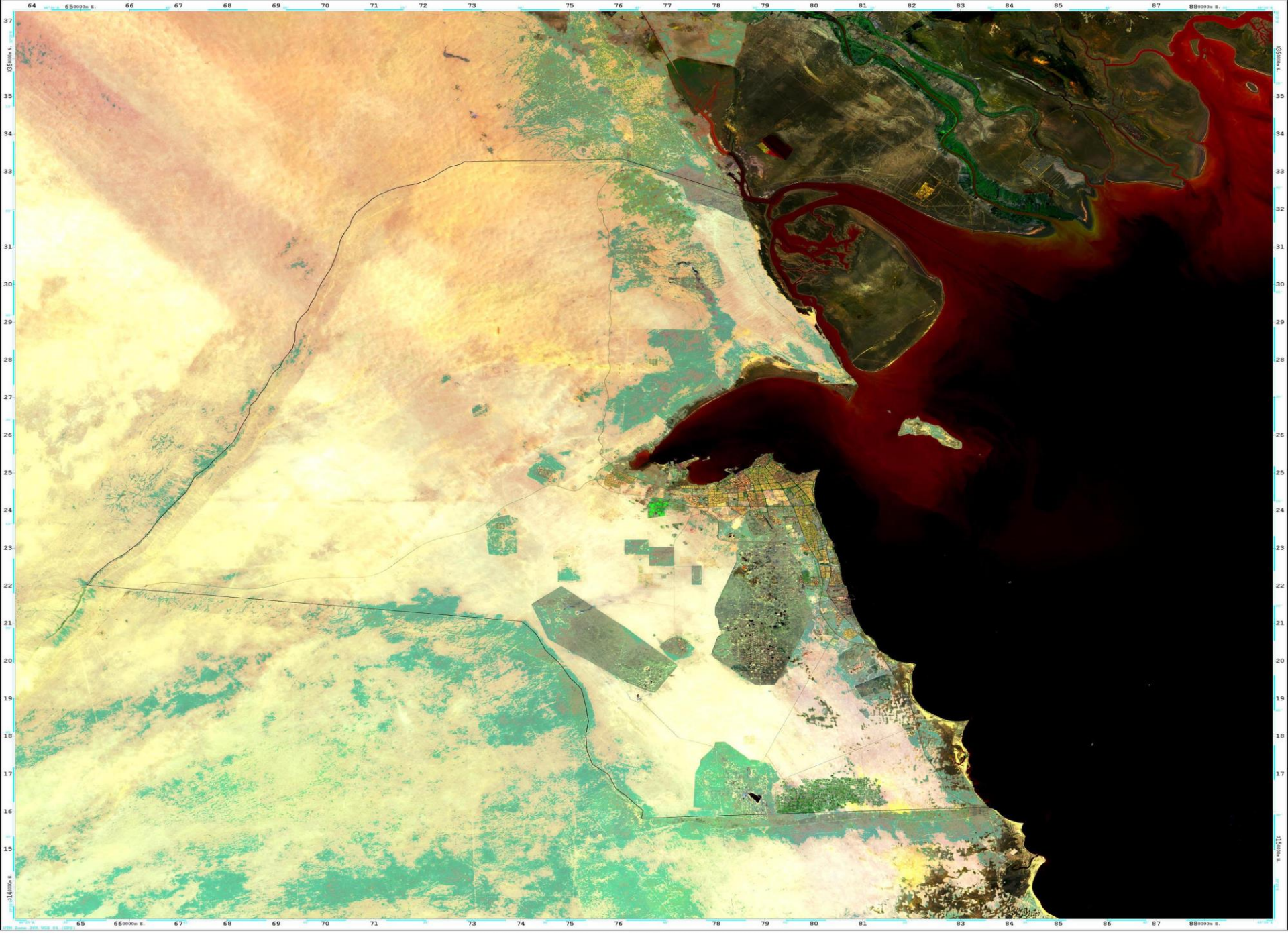
Dust phenomena, Kuwait case study

Ali M. Al-Dousari

International workshop on sand & dust storms (4-7 Oct 2016-Istanbul-Turkey)



6-OCT-2016



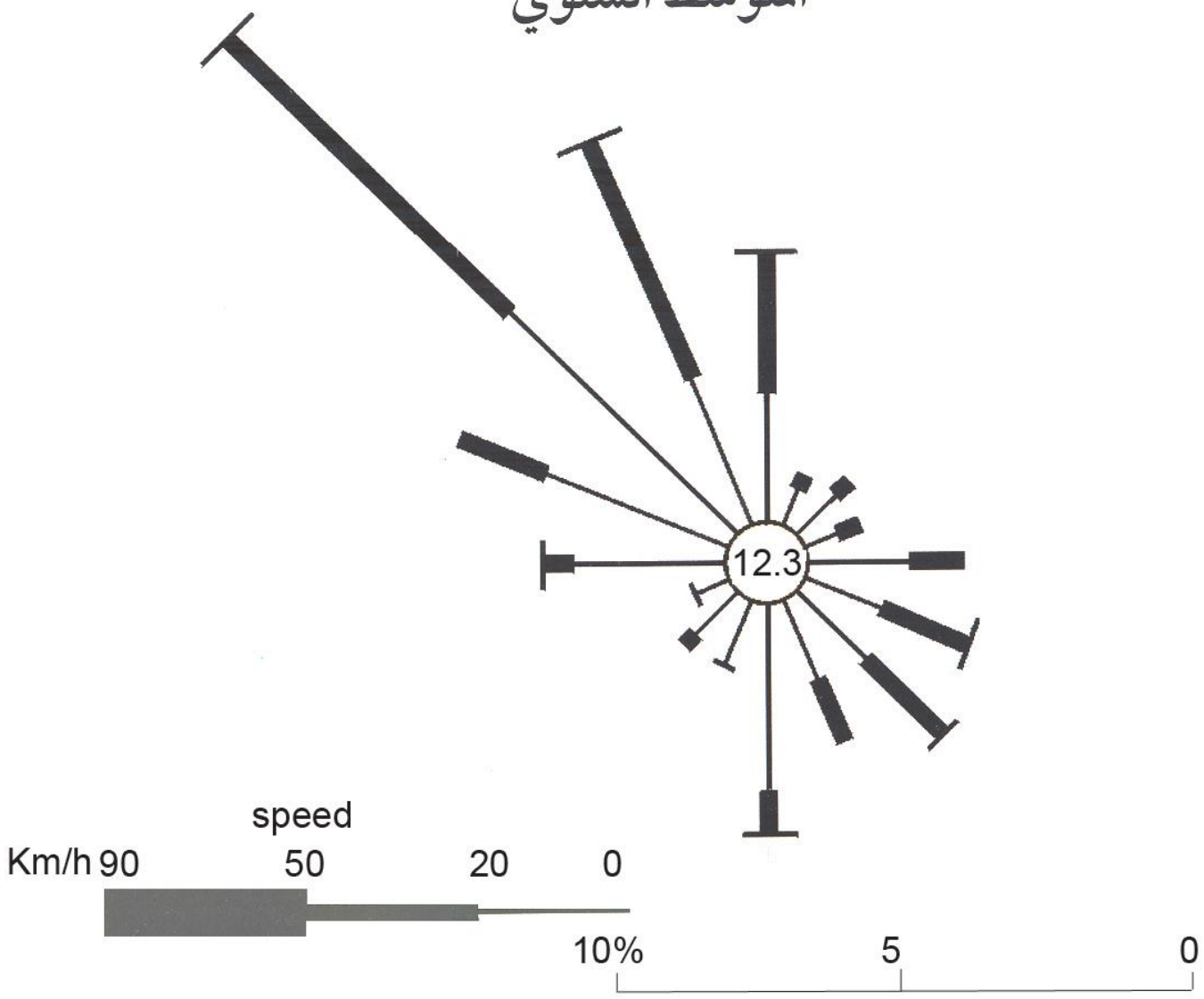
Landsat image of Kuwait in bands 2, 4 and 7 for the year 2003

1:250 000 Scale

Kilometres 10 0 10 20 30

Miles 10 0 10

المتوسط السنوي



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Human Effect

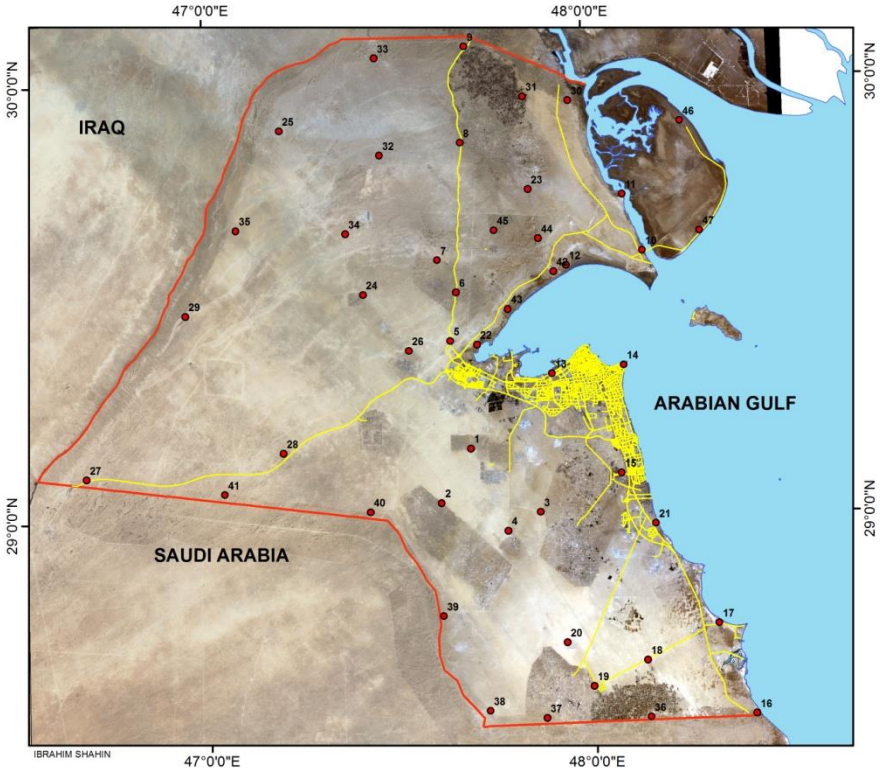
Mean Number of Days and Hours of Dust Phenomena at Kuwait International Airport (Safar, 1985) (1954-1984)

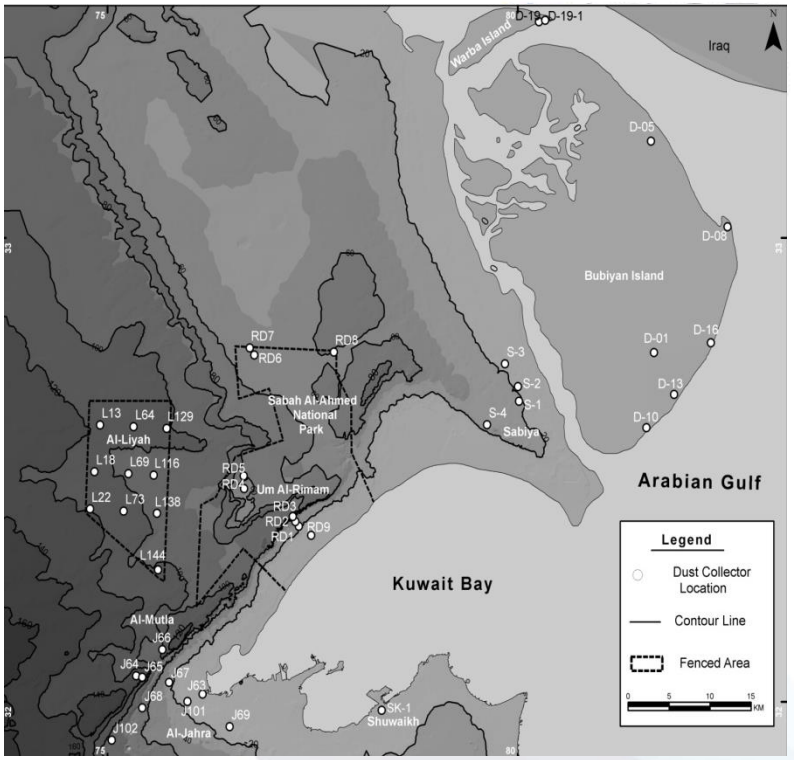
Month	Dust/Sand Storms		Raising dust		Suspended dust		Haze	
	Days	Hours	Days	Hours	Days	Hours	Days	Hours
January	1.1	4.2	3.7	22.0	3.1	15.4	7.7	47.5
February	1.3	4.7	4.3	35.2	4.4	21.7	7.5	51.2
March	2.1	7.2	6.1	45.7	4.7	38.0	7.6	76.0
April	3.2	11.2	6.1	43.9	5.2	43.8	7.4	81.1
May	4.2	12.7	6.7	51.8	6.2	52.0	7.5	106.3
June	4.8	31.7	10.3	108.3	4.7	56.3	6.4	93.3
July	4.4	31.3	8.4	92.7	5.7	55.1	7.3	94.4
August	2.3	11.2	8.3	75.6	5.2	38.9	8.9	97.4
September	0.6	2.5	5.1	31.4	6.0	25.7	11.3	96.2
October	1.5	4.8	3.6	22.9	5.7	26.2	10.7	79.7
November	0.4	0.9	2.9	14.8	4.0	18.1	10.3	56.0
December	1.1	5.3	3.4	18.3	3.2	14.4	8.8	51.0
Annual Total	27.0	127.7	68.9	562.6	58.1	405.6	101.4	930.1

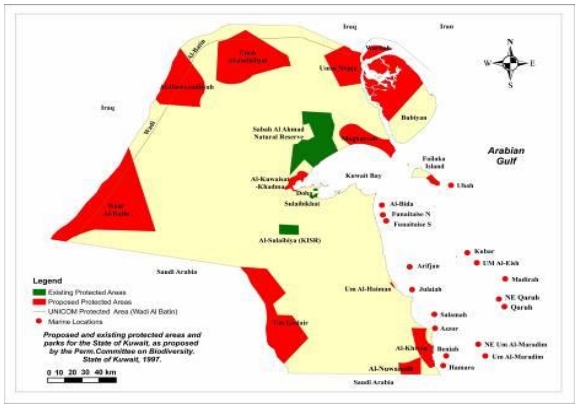
The average number for dust storm days in the Arabian Gulf (Source: Al-Kulaib, 1990 after modification).

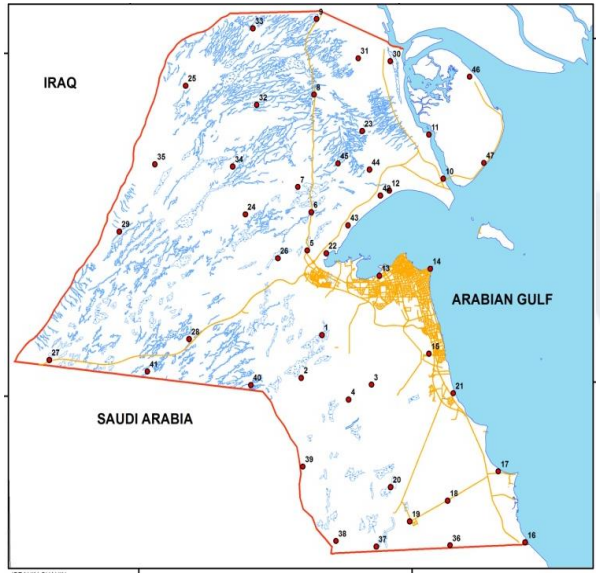
*** Kuwait data from this study from July 2000 to March 2010.**

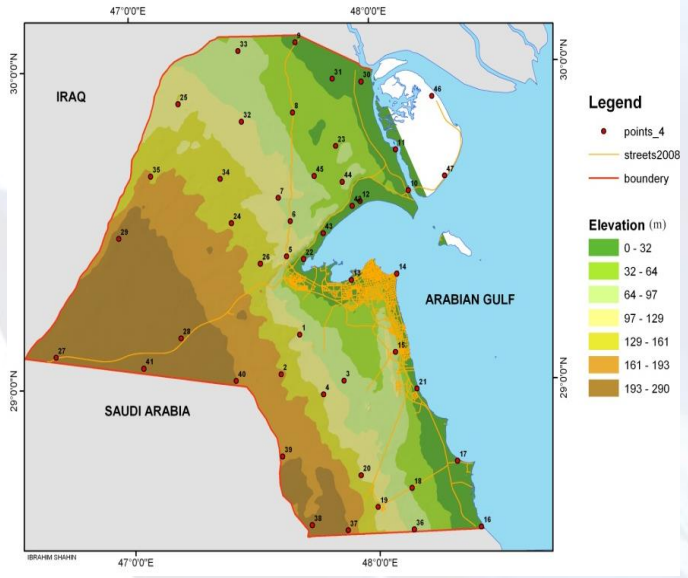
Station	No. of years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annually Average
Kuwait*	11	0.9	1.2	1.1	3.3	3.7	4.4	4.5	1.9	0.6	1.4	0.3	1.1	21
Bahrain	33	0.1	0.3	0.5	0.6	0.5	1.4	1.5	0.2	0.3	0.0	0.1	0.1	5.6
Doha	15	0.4	0.5	0.7	0.7	0.4	1.7	1.4	0.4	0.4	0.3	0.4	0.1	7.6
Abu Dhabi	6	0.4	0.3	0.6	0.1	0.4	0.4	0.7	0.0	0.0	0.0	0.2	0.7	3.9


47°0'0"E
48°0'0"E
30°0'0"N
29°0'0"N
IRAQ
SAUDI ARABIA
ARABIAN GULF
IBRAHIM SHAHIN

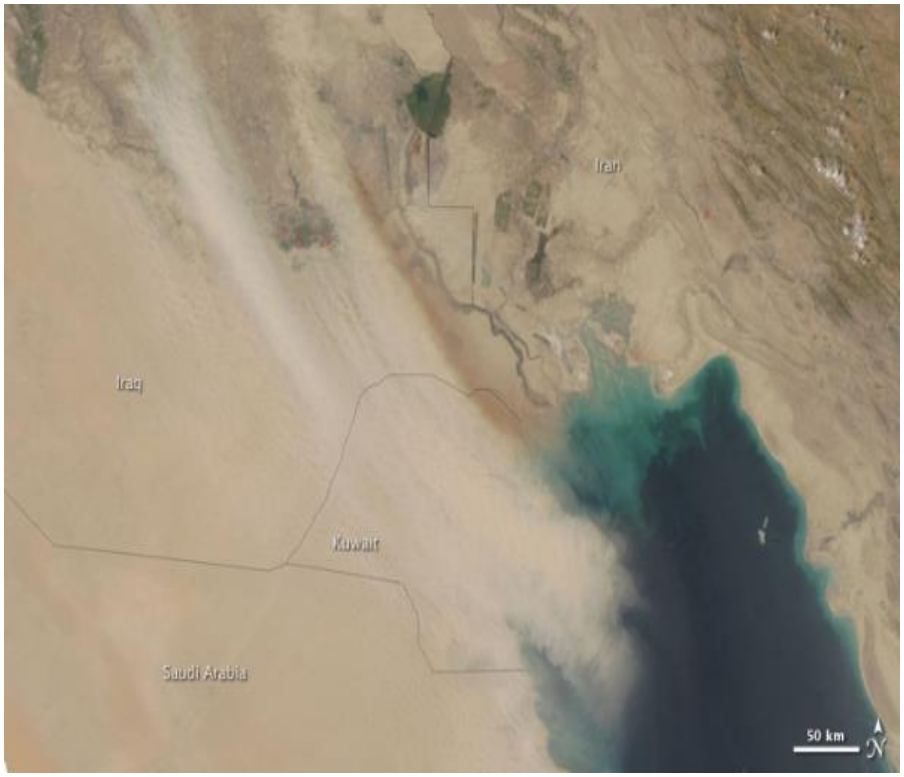

Iraq
Warba Island
Bubiyan Island
Arabian Gulf
Kuwait Bay
Sabah Al-Ahmed National Park
Al-Liyah
Um Al-Rimam
Sabiya
Al-Mutla
Al-Jahra
SK-1
Shuwaikh
Legend
Dust Collector Location
Contour Line
Fenced Area


Iraq
Iran
Saudi Arabia
Kuwait Bay
Bubiyan
Failaka Island
Arabian Gulf
Sabah Al Ahmad Natural Reserve
Al-Subahiya (KISR)
Legend
Existing Protected Areas
Proposed Protected Areas
UNICOM Protected Area (Wadi Al Batin)
Marine Locations
Proposed and existing protected areas and parks for the State of Kuwait, as proposed by the Perm. Committee on Biodiversity. State of Kuwait, 1997.
0 10 20 30 40 km

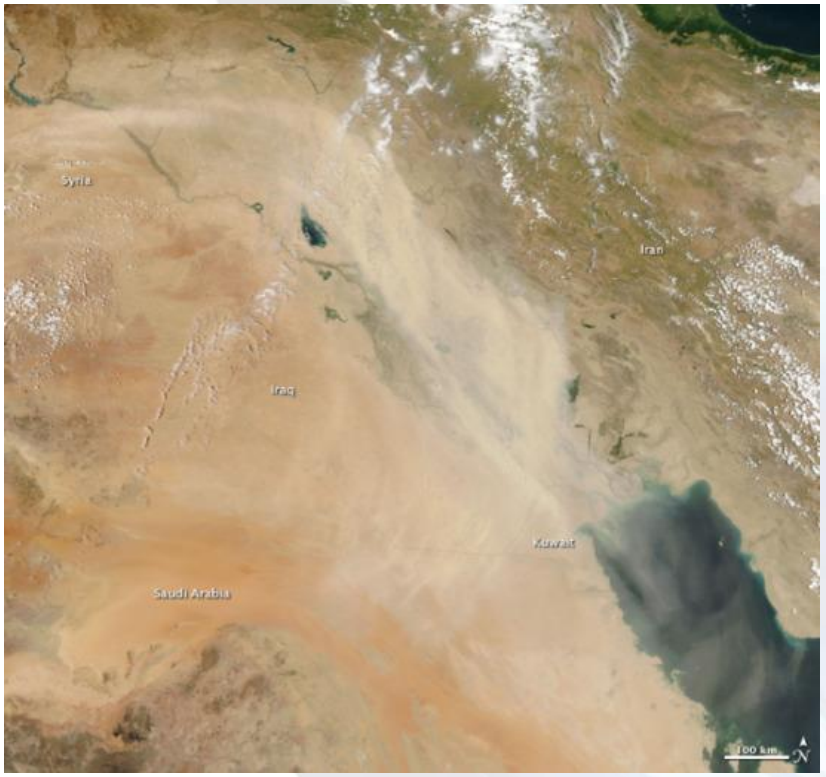

IRAQ
SAUDI ARABIA
ARABIAN GULF

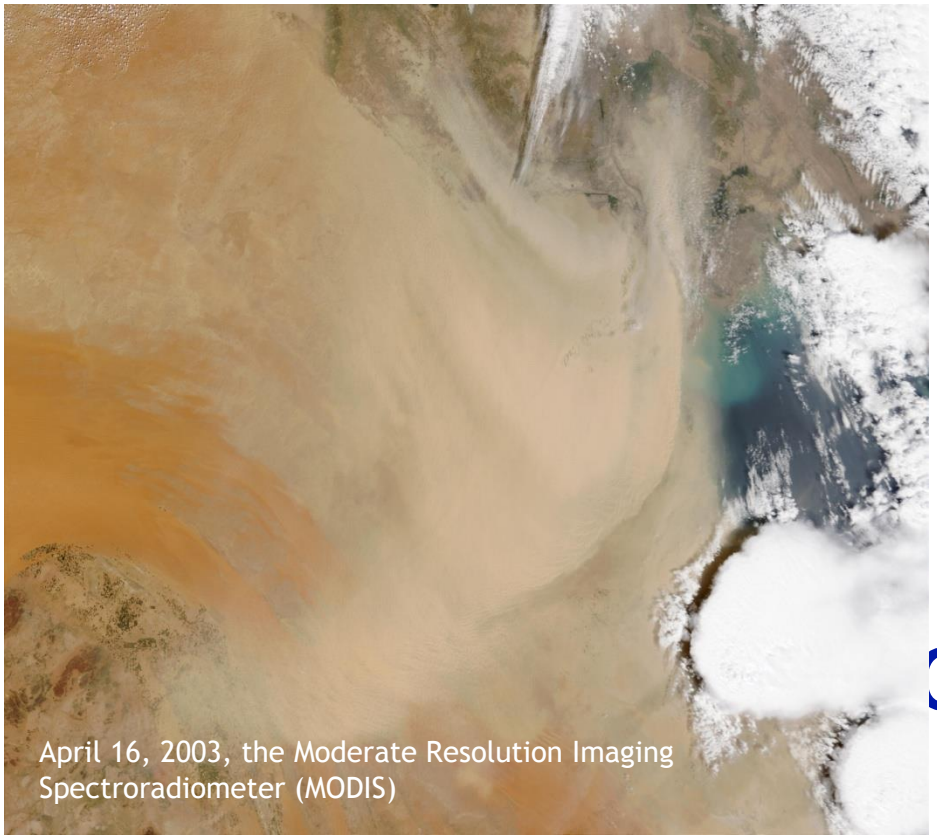

47°0'0"E
48°0'0"E
30°0'0"N
29°0'0"N
IRAQ
SAUDI ARABIA
ARABIAN GULF
IBRAHIM SHAHIN
Legend
points_4
streets2008
boundery
Elevation (m)
0 - 32
32 - 64
64 - 97
97 - 129
129 - 161
161 - 193
193 - 290

August 15, 2009. Moderate Resolution Imaging Spectroradiometer (MODIS) detected fires

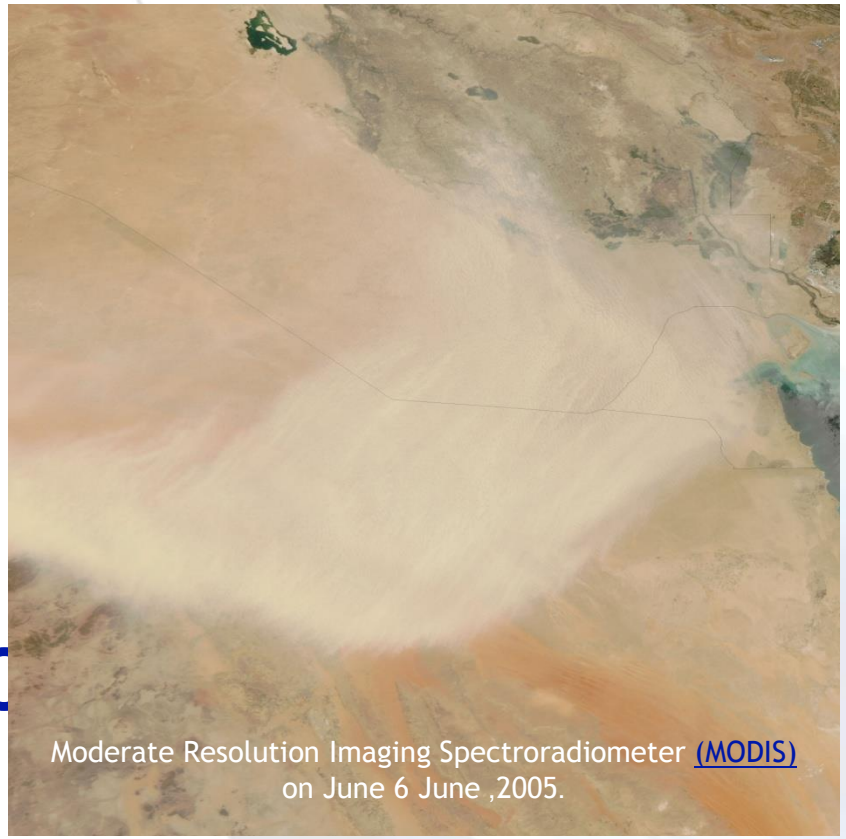


7 June 2010 -Aqua satellite.

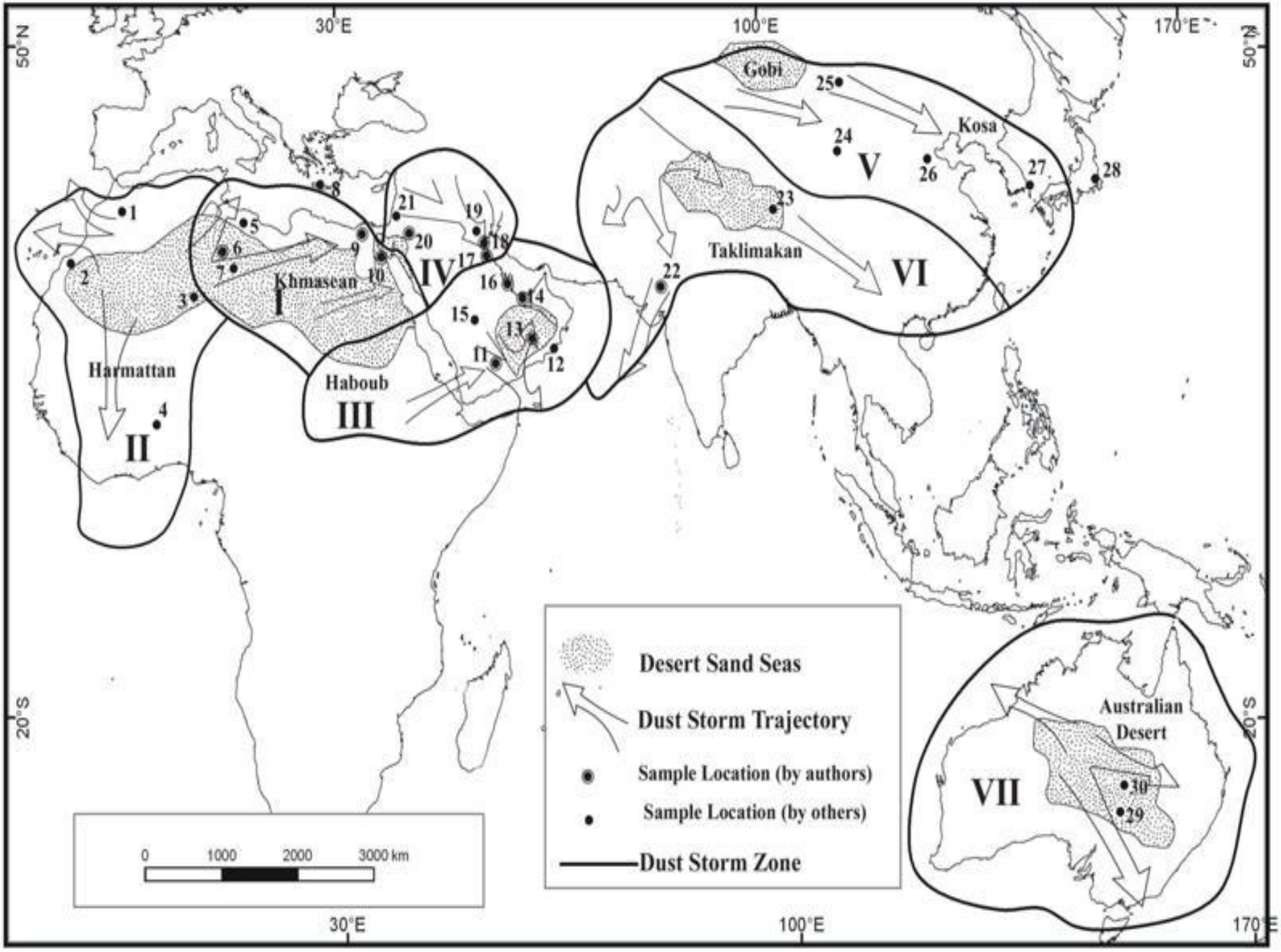




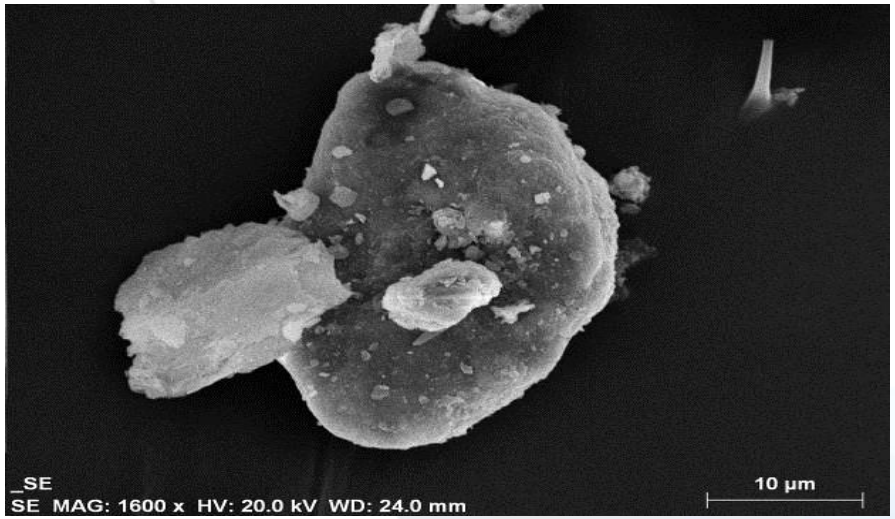
April 16, 2003, the Moderate Resolution Imaging Spectroradiometer (MODIS)

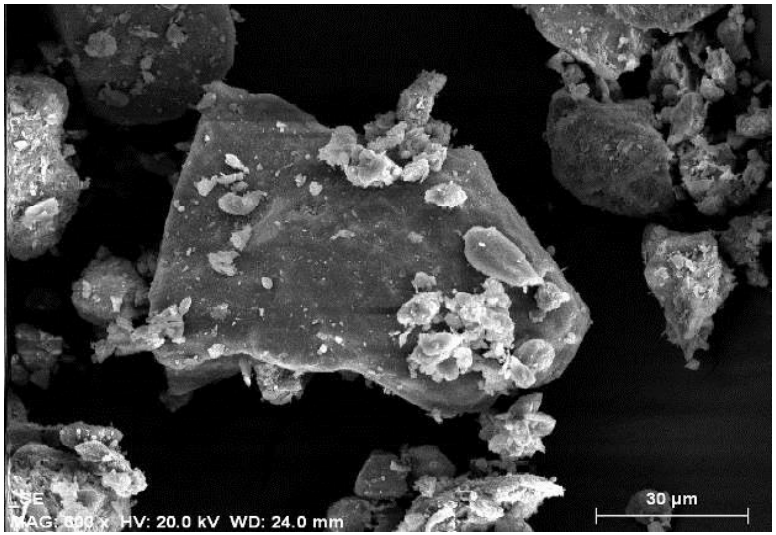


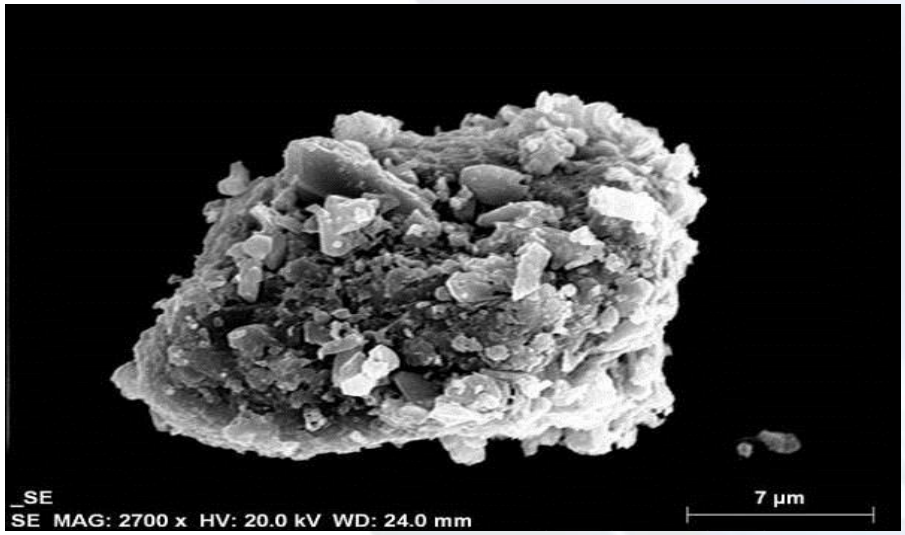
Moderate Resolution Imaging Spectroradiometer (MODIS) on June 6 June ,2005.

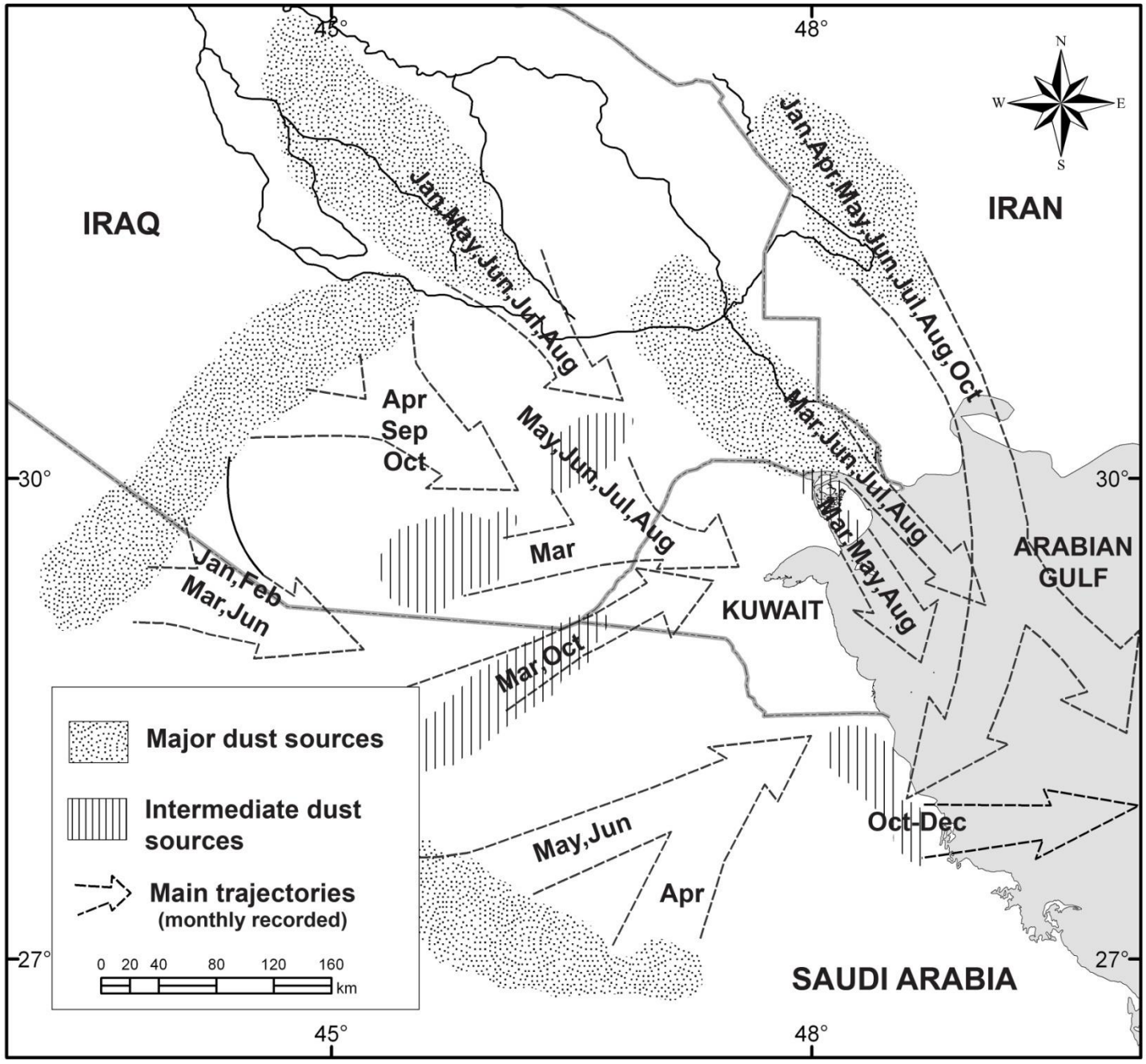

50°N
30°E
100°E
170°E
20°S
Gobi
Kosa
Taklimakan
Khmasean
Harmattan
Haboub
Australian Desert
I
II
III
IV
V
VI
VII
Desert Sand Seas
Dust Storm Trajectory
Sample Location (by authors)
Sample Location (by others)
Dust Storm Zone
0 1000 2000 3000 km

Smooth dust particles within West Rub Al-Khali with dominancy of very coarse silt (a), sub-angular quartz grain with some adhering carbonates particles (b), and 30 µm carbonate particles from Bubiyan with huge number of adhering gypsum and bassanite particles (c &d).



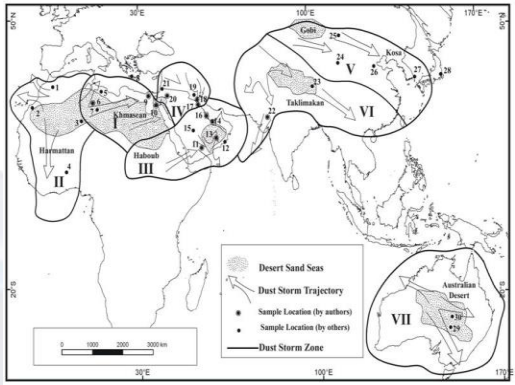





45°
48°
N
W
E
S
IRAQ
IRAN
Jan,May,Jun,Jul,Aug
Jan,Apr,May,Jun,Jul,Aug,Oct
Apr
Sep
Oct
May,Jun,Jul,Aug
Mar,Jun,Jul,Aug
30°
Mar
Mar,May,Aug
ARABIAN
GULF
Jan,Feb
Mar,Jun
KUWAIT
Mar,Oct
Major dust sources
Intermediate dust sources
Main trajectories
(monthly recorded)
0 20 40 80 120 160
km
May,Jun
Oct-Dec
Apr
27°
SAUDI ARABIA
45°
48°

Amount of fallen dust (monthly and annual)

Zone-Location	Political region	Reference	Tons.Km^{-2}.mo^{-1}	Tons.km^{-2}.yr^{1}
Zone I: The western and southern Sahara Desert				
A long Niger River	Mali	McTainsh et al,. 1997	75-858	913-10446
Northern Diarnena	Chad	Maley, 1982	11.83	142
Kano	Nigeria	McTainsh et al,. 1982	11.4-15.1	137-181
Southern Chad	Chad	Maley, 1982	9.08	109
Nouadhibou	Mauritania	Rott, 2001	6.54	80
Smara	Western Sahara	Rott, 2001	9.12	111
Agadir	Morocco	Rott, 2001	9.39	114
Sidi Ifni	Morocco	Rott, 2001	11.88	145
Tan Tan	Morocco	Rott, 2001	14.37	175
Dakhla	Mauritania	Rott, 2001	15.72	191
Boujdour	Western Sahara	Khiri et al, 2004	17.97	219
Zone II: The eastern Sahara Desert				
Libya	Libya	O'Hara et al., 2006	13	155
Negev Desert	Palestine	Singer et al., 2003	4.8-18.1	57-217
Crete	Greece	Pye, 1992	0.83-8.33	10-100
Zone III: Sudan-Ethiopia and southern Arabia				
Fahal	Oman	Badawy et al., 1992	7.4	89
Riyadh	Saudi Arabia	Modaihsh, 1997	32.67	392
Zone IV: Northern Arabia				
Dead Sea	Palestine	Singer et al., 2003	3.71	45
Khur Al-Zubir	Iraq	Khalaf et al., 1980	6.9	75.92
Um Qasr	Iraq	Gharib et al., 1987	17.59	193.47
Kuwait	Kuwait	Present study	22.5	270
Zones V and VI: Gobi and Taklimakan deserts				
Xilingele	Mongolia	Hoffmann et al., 2008	24	292
Shapotou	China	Li et al., 2004	31	372
Tokyo	Japan	MOE, 1993	0.29	3.5
Zone VII: Australia Desert				
Adelaide	Australia	Tiller et al., 1987	0.42-0.83	5-10
Namoi valley	Australia	Cattle et al., 2002	1.4-4.85	16.9-58.2



Trajectory zone	Particle size percentages							Reference
	Sand	V.C.Silt	C.Silt	M.Silt	F.Silt	V.F.Silt	Clay	
Zone I: The western and southern Sahara Desert								
Tripoli-Libya	20	12	17	19	17	8	8	O'Hara et al., 2006
Biougra-Morocco	12	28	22	16	8	8	6	Khiri et al.,2004
Cartagena-Colombia	10	4	18	22	18	12	16	Present study
Arizona-USA	9	26	30	13	8	4	10	Pewe et al.,1981
Average	13	18	22	18	13	8	10	
Zone II: Eastern Sahara Desert								
Tripoli-Libya	20	12	17	19	17	8	8	O'Hara et al., 2006
Cairo-Egypt	10	15	37	21	10	4	3	Present study
Average	15	14	27	20	14	6	6	
Zone III: Sudan-Ethiopia and southern Arabia								
Wadi Dawasir	40	8	21	15	11	2	4	Present study
Ain	97	0	1	1	1	1	0	Present study
Dubai	17	3	14	24	23	10	8	Present study
Average	51	4	12	13	12	4	4	
Zone IV: Northern Arabia								
Amman-Jordan	30	11	30	17	8	2	2	Present study
Um Qasr-Iraq	3	12	20	25	15	5	20	Khalaf et al., 1980
Kuwait	37	22	18	14	7	2	0	Present study
Manamah-Bahrain	12	10	20	11	13	5	28	Present study
Average	21	14	22	17	11	4	13	
Zone V and VI: Gobi and Taklimakan deserts								
Taklimakan-China	70	24	2	1	2	1	0	Nishikawa et al.,2000
Ejin-China	35	18	10	8	5	2	22	Wang et al., 2005
Siberia-Russia	11	31	28	11	7	4	8	Pewe,1981
Average	39	24	13	7	5	2	10	
Zone VII: Australian Desert								
Bald Hill-Australia	9	3	5	5	4	3	70	Cattle et al., 2002
Average	26	14	18	14	10	5	13	
Max	97	31	37	25	23	12	70	
Min	3	0	1	1	1	1	0	

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Grain size % of Fallen dust from upwind to downwind

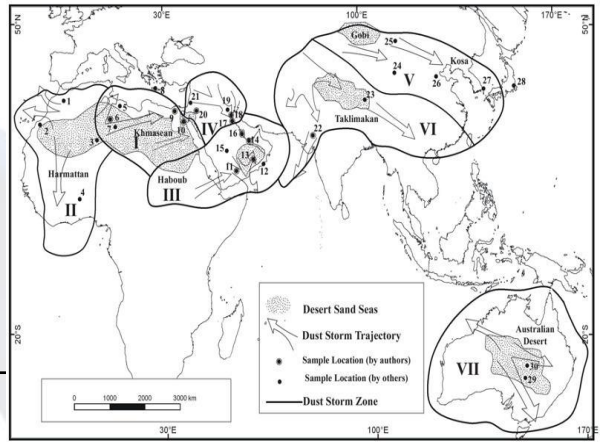

Table. The amount in m^3 and cost in USD of sand removal from civil and military facilities

Settlements	Total Sand Removed (m^3)	Total Cost (USD)	Cost for removal for m^3 (USD)	Total Amount of Sand Removal (m^3)	Total Cost of Sand Removal (USD)	Cost for sand removal for m^3 (USD)
		1993			2013	
Kuwait Oil facilities	283,545	717,811	2.53	347,310	993,862	2.87
Main Highways	779,855	913,272	1.17	2,651,431	2,141,757	0.81
Power stations	42,500	121,618	2.86	160,600	955,452	5.95
Military Base	650,700	357,700	0.55	1,320	78,694	59.61
Average	439,150	527,600	1.78	790,165.13	1,042,441	5.33
Total	1,756,600	2,110,401		3,160,660.52	4,169,766	

Table. The costs of sand removal in Kuwait comparing to surrounding regions.

Area	Reference	Year	Sand removal cost of m^3 (USD)
Kuwait	Present study	1993	1.78
Kuwait	Present study	2013	5.33
Hofouf-Saudi	Alghamdi and Al-Kahtani, 2005	2004	0.50
Riyadh-Saudi	Al-Hareeq, 2012	2007	3.73
Riyadh-Saudi	Al-Hareeq, 2012	2012	0.80
Bushra-Syria	Alobaid, 2000	1996	0.09
Sistan-Iran	Pahlavanravi et al., 2012	2000	2.00
Sistan-Iran	Pahlavanravie et al., 2012	2004	0.50

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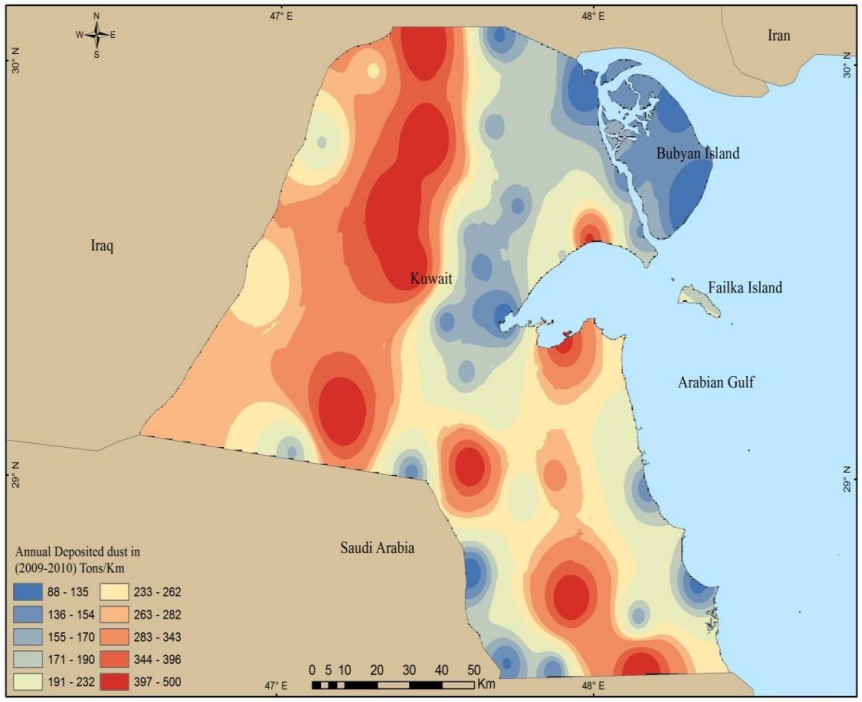
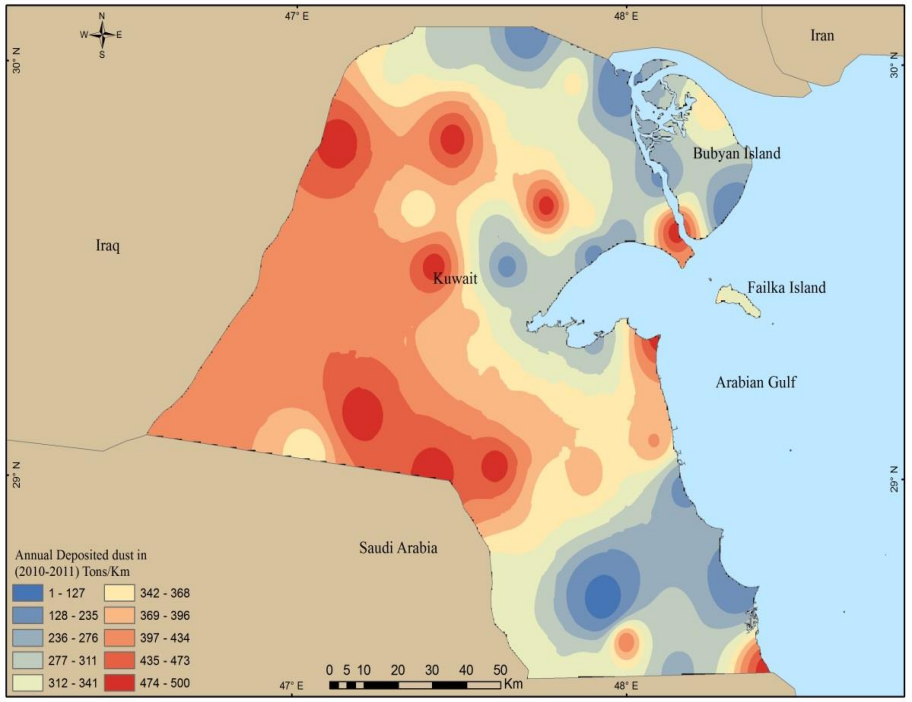
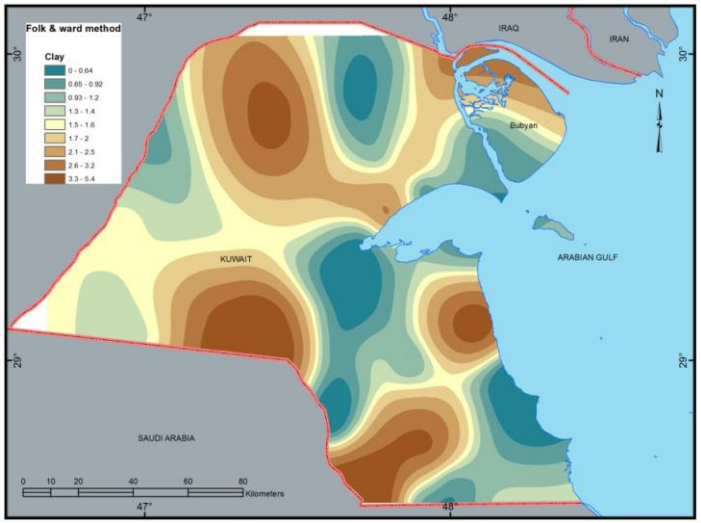
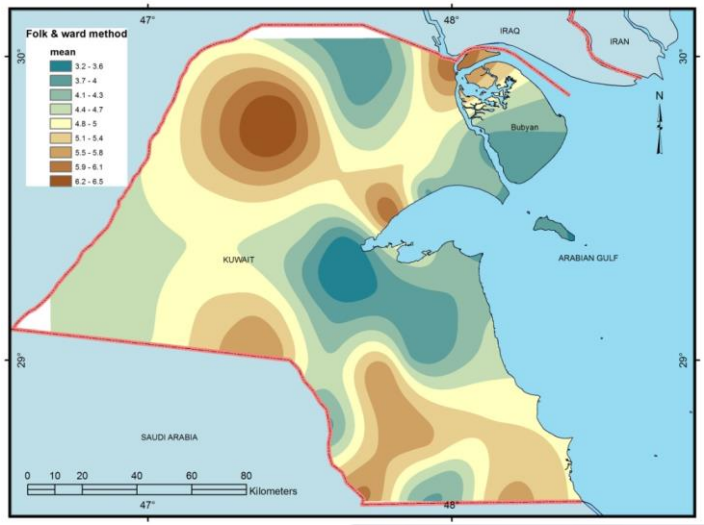




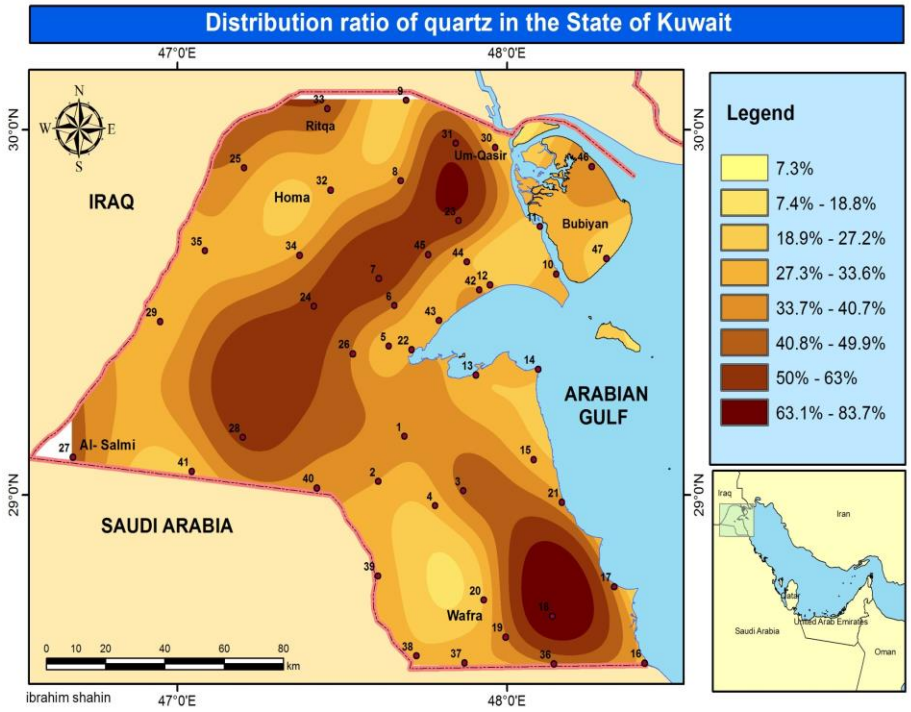
Annual dust comparison between (2009/2010) and (2010/2011)

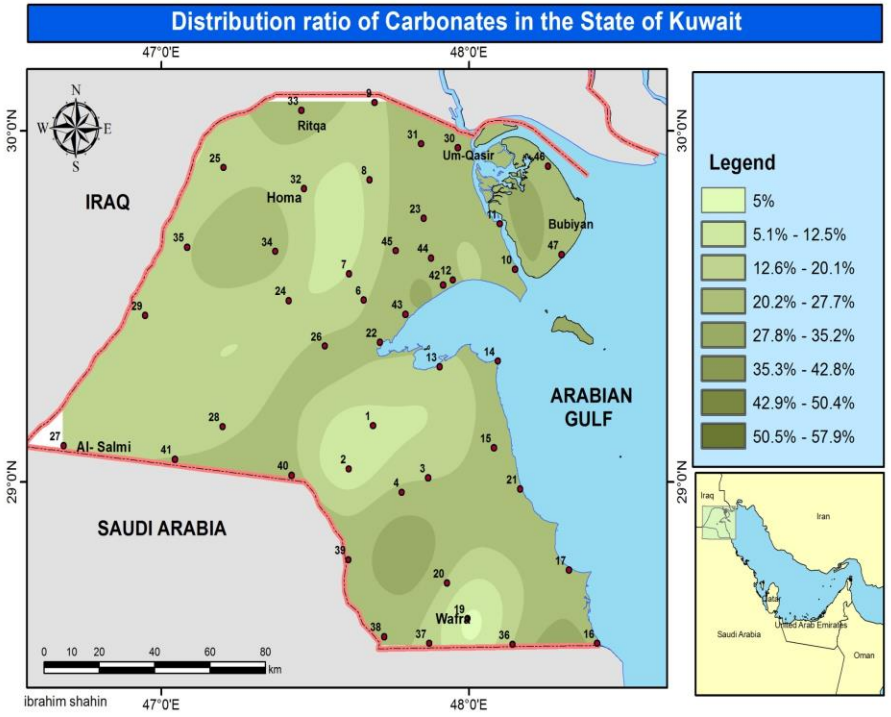




Clay % and mean particle size

Mineralogy (Quartz and Carbonates %)





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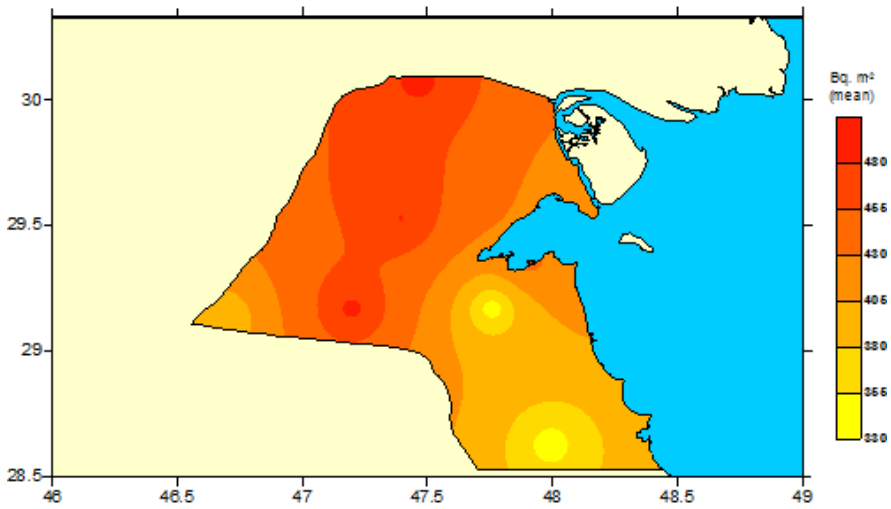
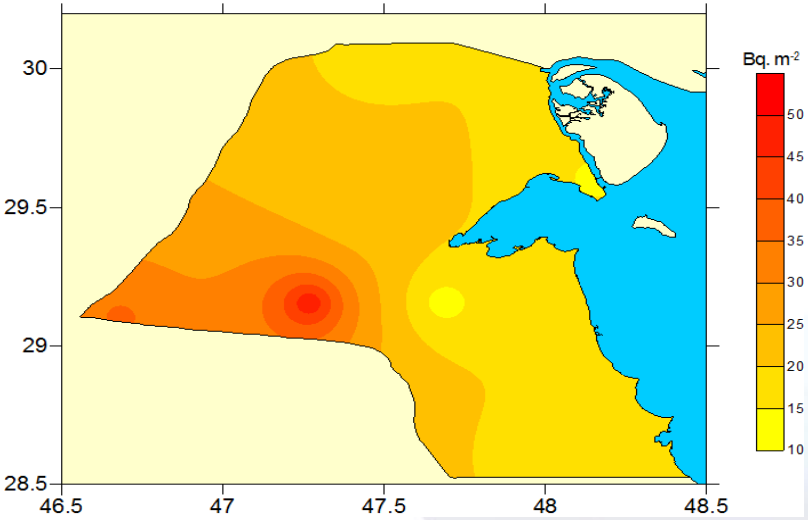
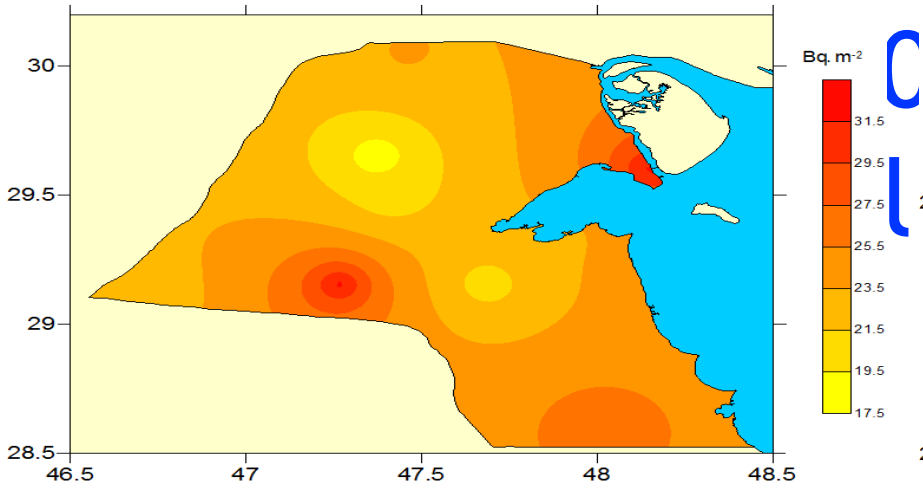
Annual variations of ^{7}Be deposition fluxes during OCT 09 - AUG 11 in Kuwait



Mean annual variations of s-137 deposition fluxes during OCT 09- AUG 11 in Kuwait



Minimum annual variations of Pb-210 deposition fluxes during OCT 09- AUG 11 in Kuwait



Mean annual variations of K-40 deposition fluxes during OCT 09- AUG 11 in Kuwait

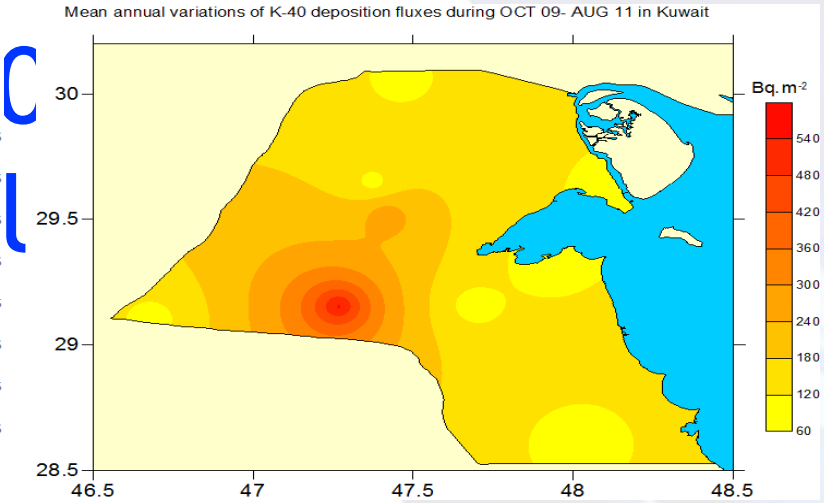
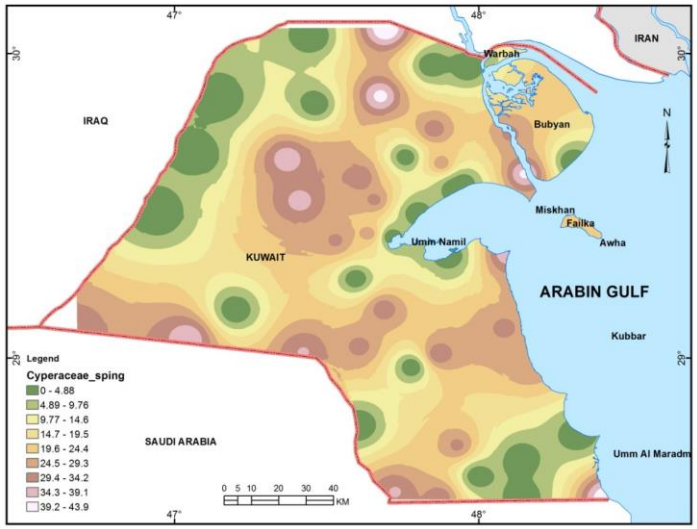
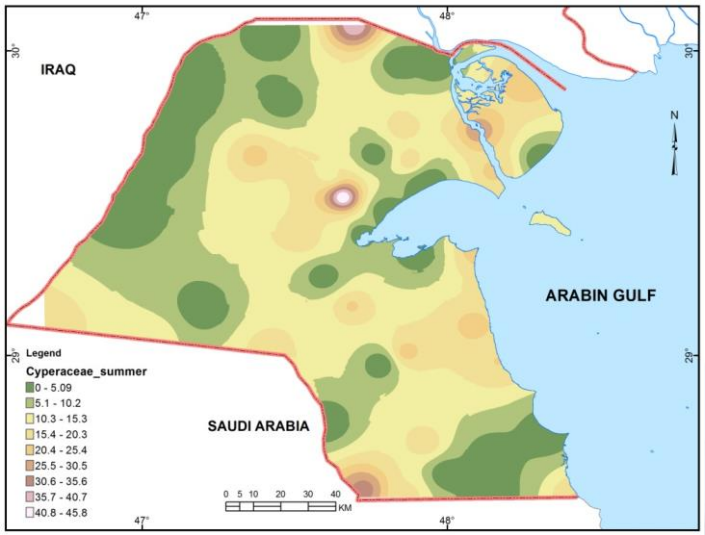


Table. The correlations between dust deposition and fallout

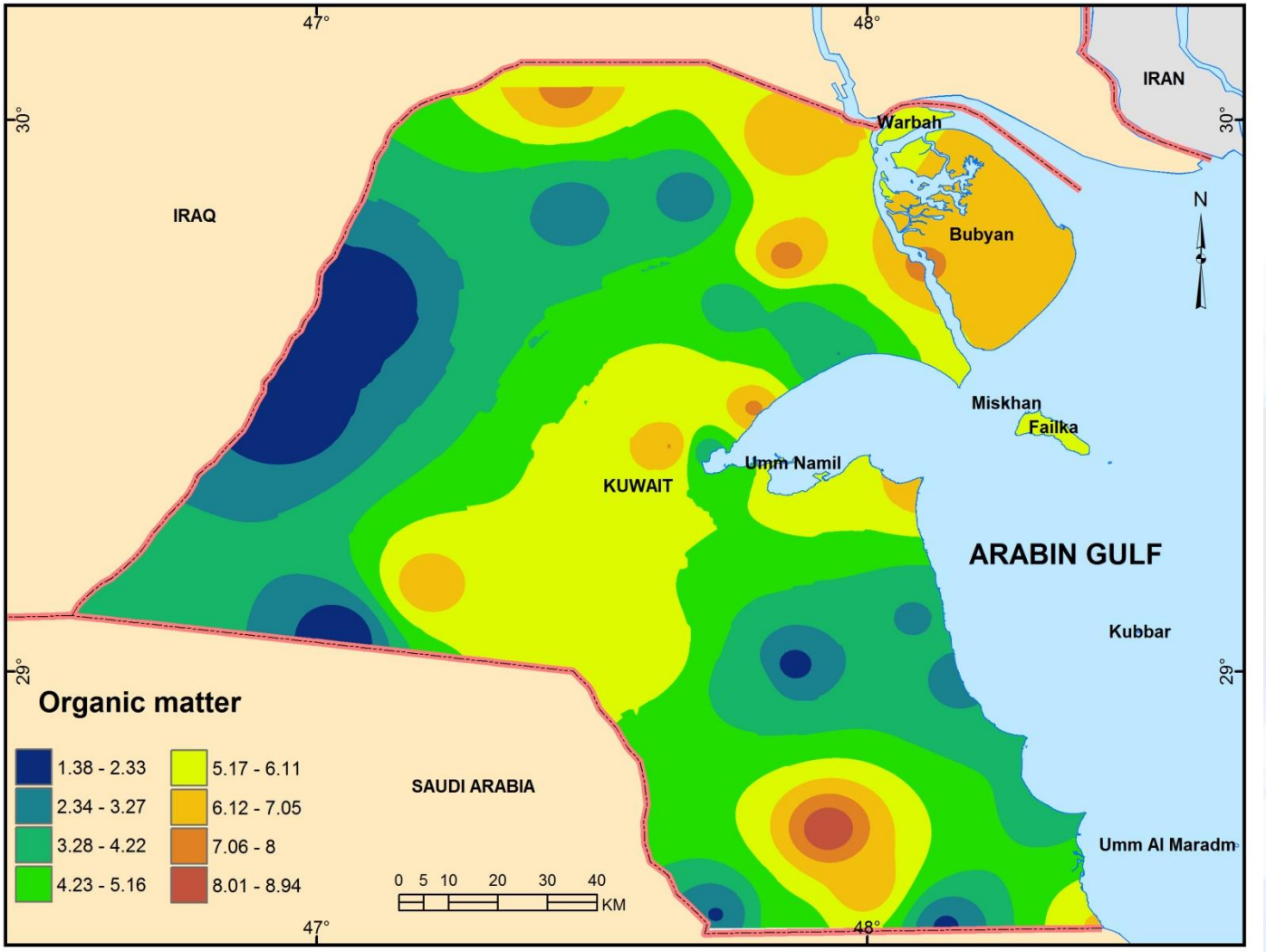
	Dust Deposition	*Be-7*	*Cs-137*	*Pb-210*	*K-40*
Dust Deposition	1				
Be-7	0.33	1			
Cs-137	0.82	0.47	1		
Pb-210	0.69	0.83	0.78	1	
K-40	0.98	0.34	0.84	0.71	1





Cyperaceae pollen Winter and summer

Organic Matter % in dust



Iron (Fe) in ppm

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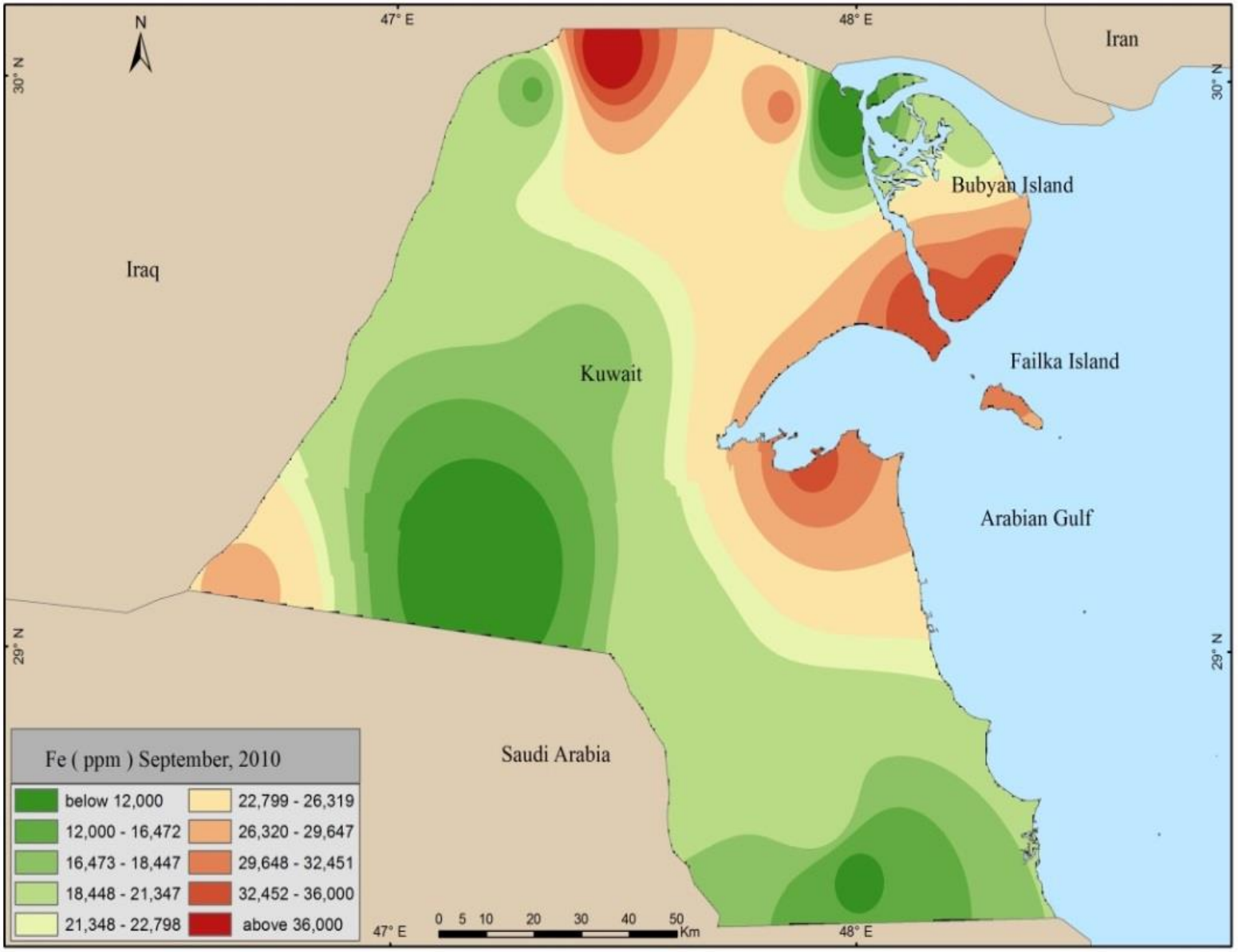
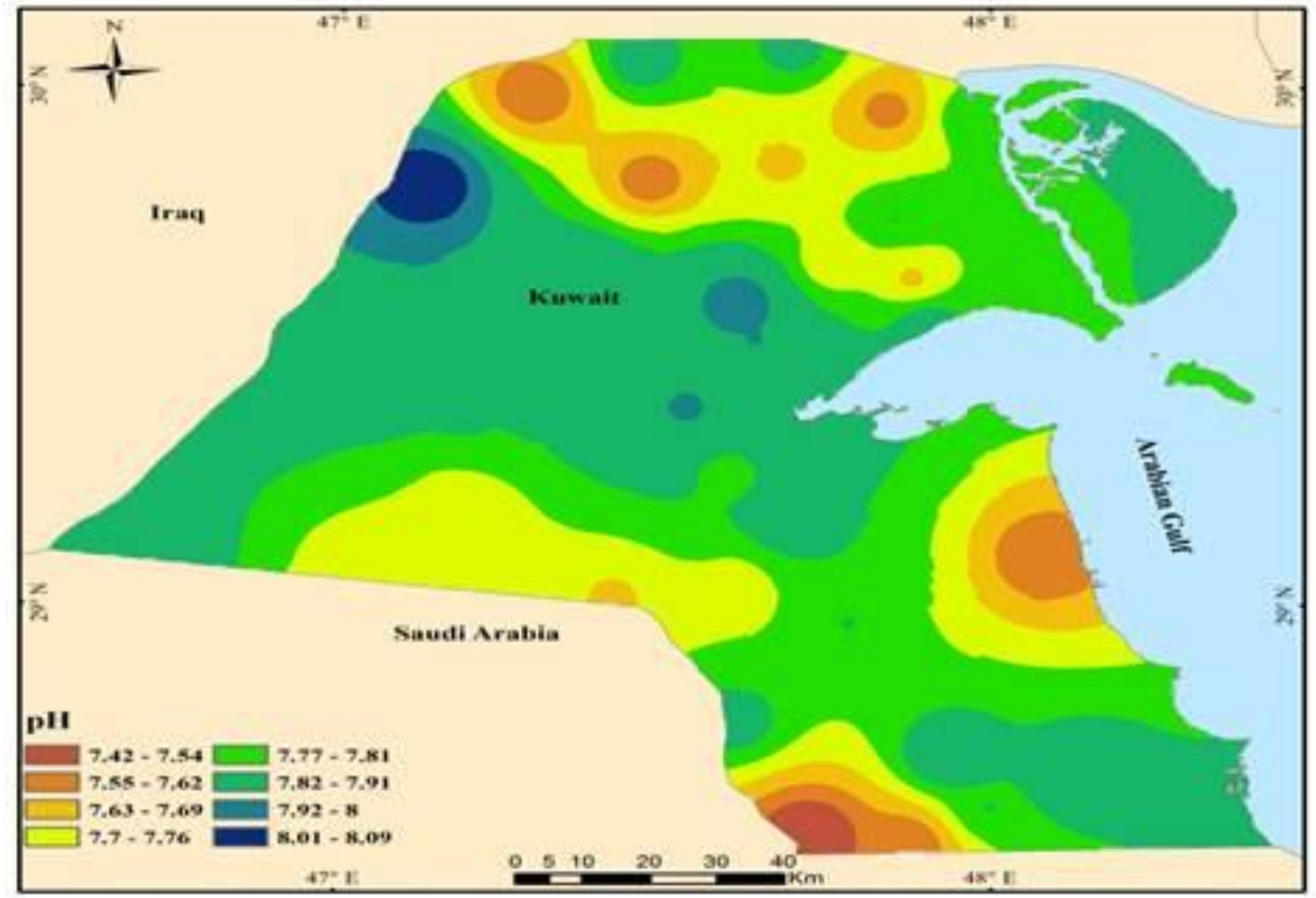
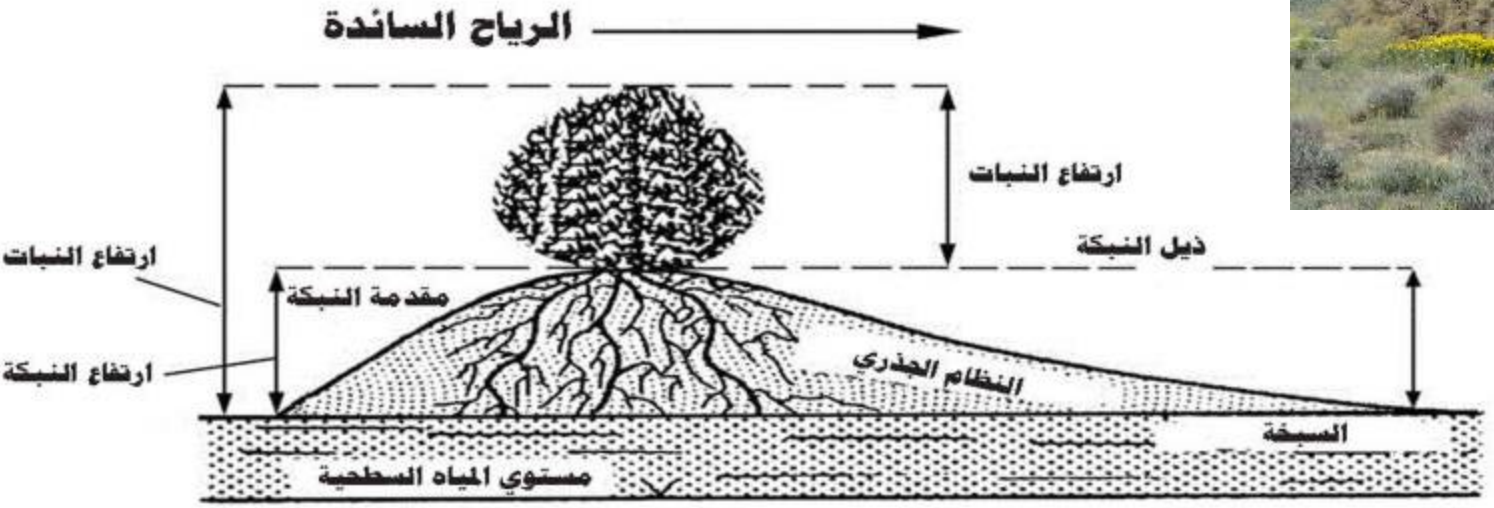
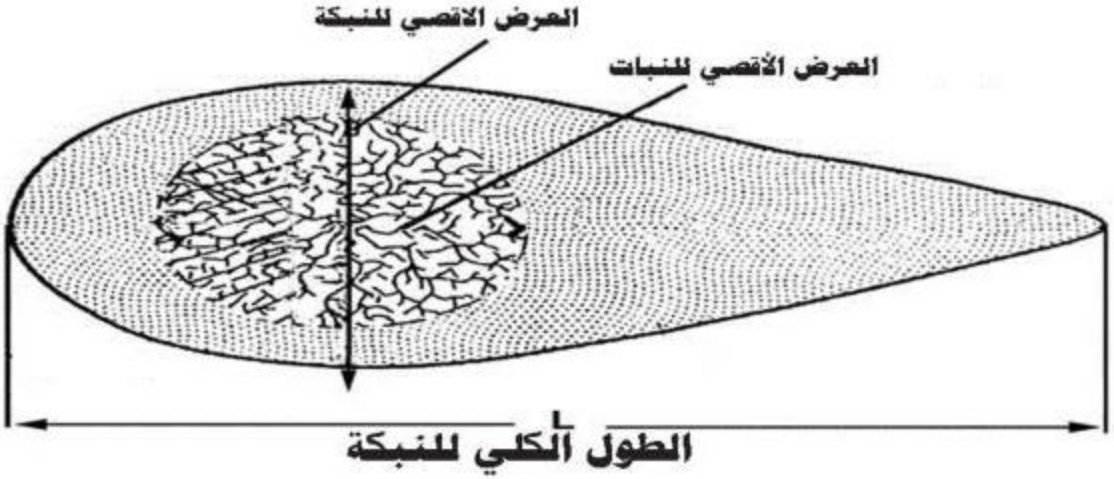



N
47° E
48° E
30° N
Iraq
Kuwait
Arabian Gulf
Saudi Arabia
29° N
pH
7.42 - 7.54
7.55 - 7.62
7.63 - 7.69
7.7 - 7.76
7.77 - 7.81
7.82 - 7.91
7.92 - 8
8.01 - 8.09
0 5 10 20 30 40
Km


الرياح السائدة
ارتفاع النبات
ذيل النبكة
ارتفاع النبات
مقدمة النبكة
ارتفاع النبكة
النظام الجذري
السبخة
مستوي المياه السطحية


العرض الاقصي للنبكة
العرض الأقصي للنبات
الطول الكلي للنبكة

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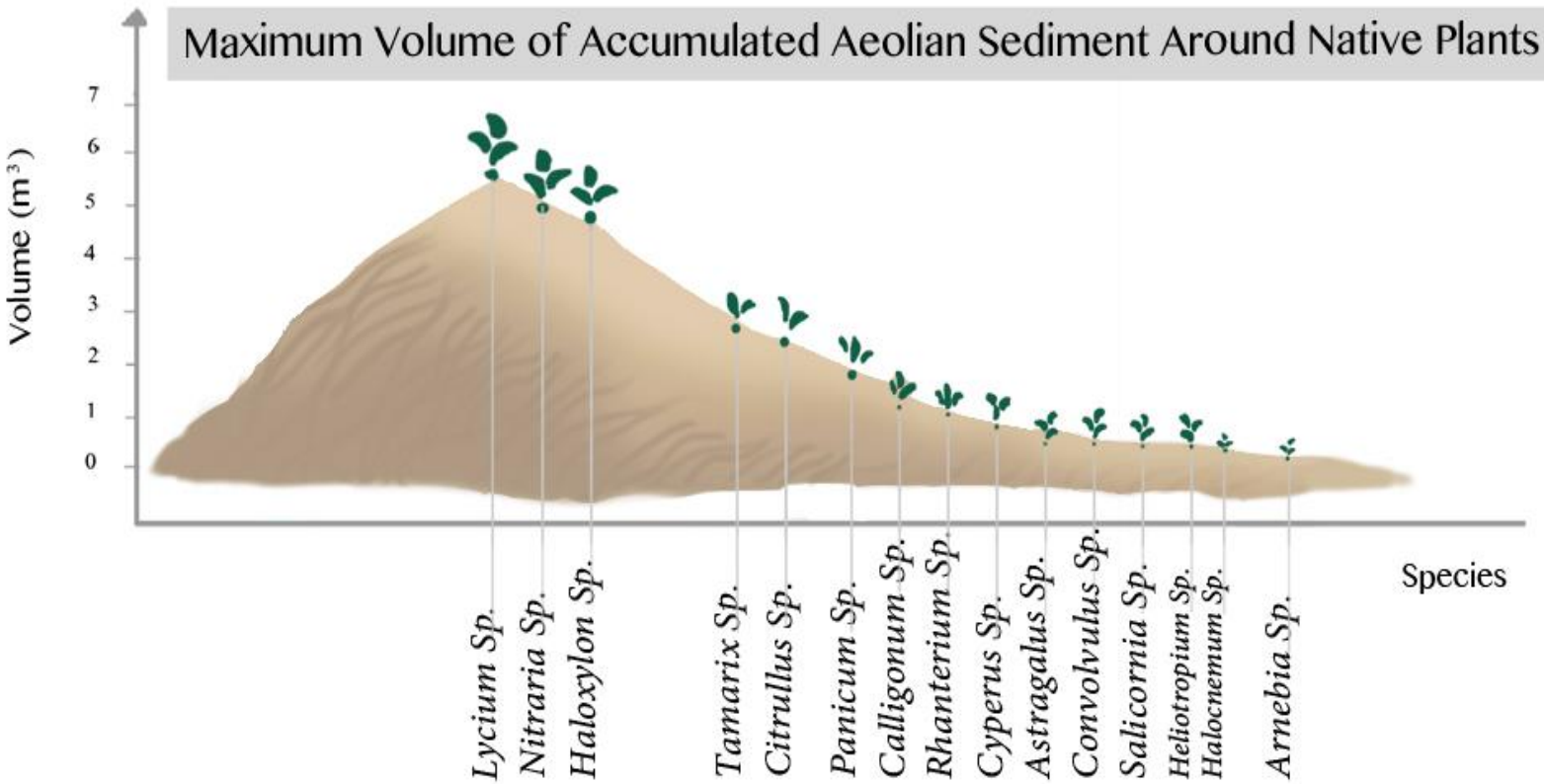
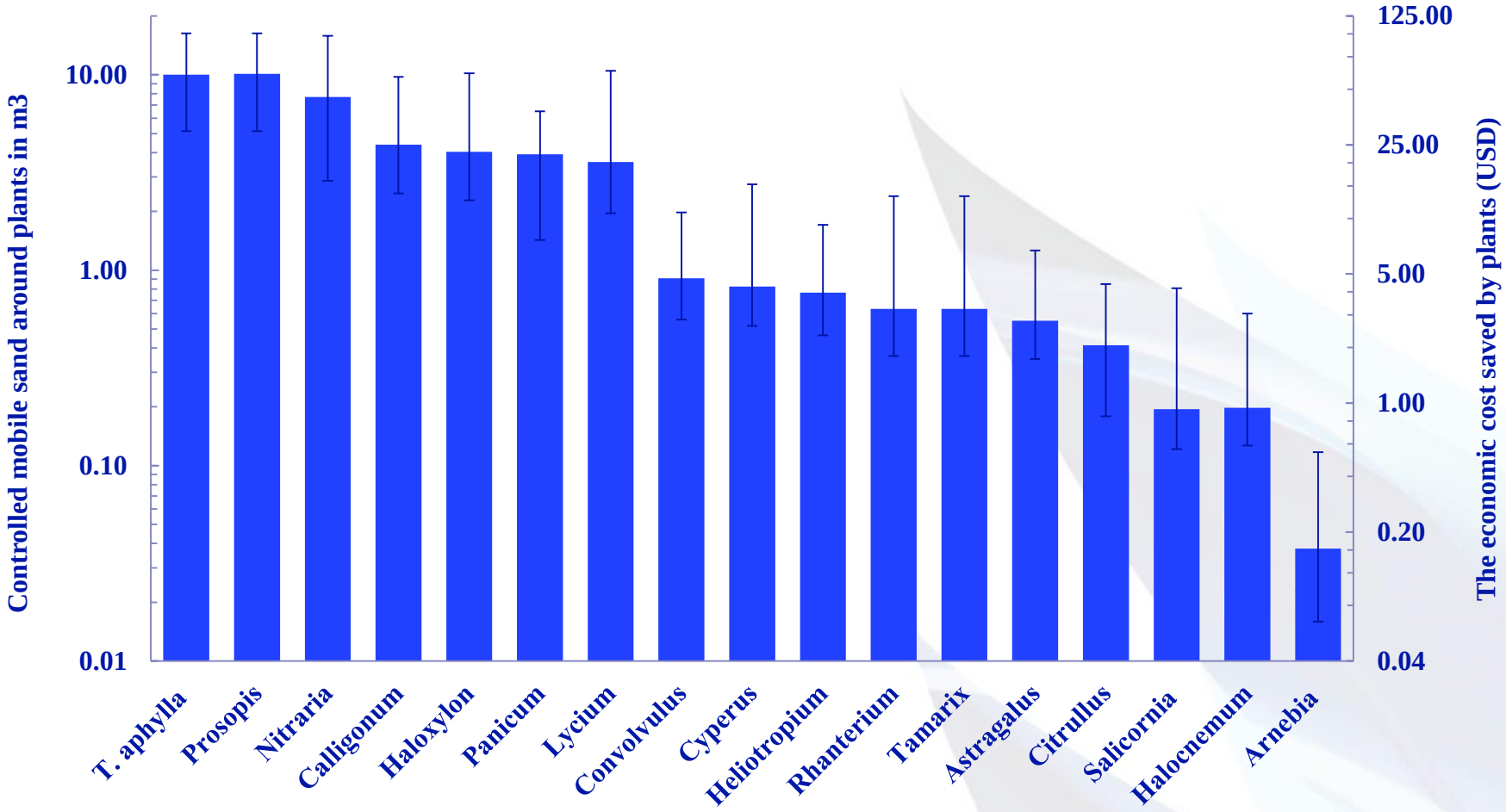
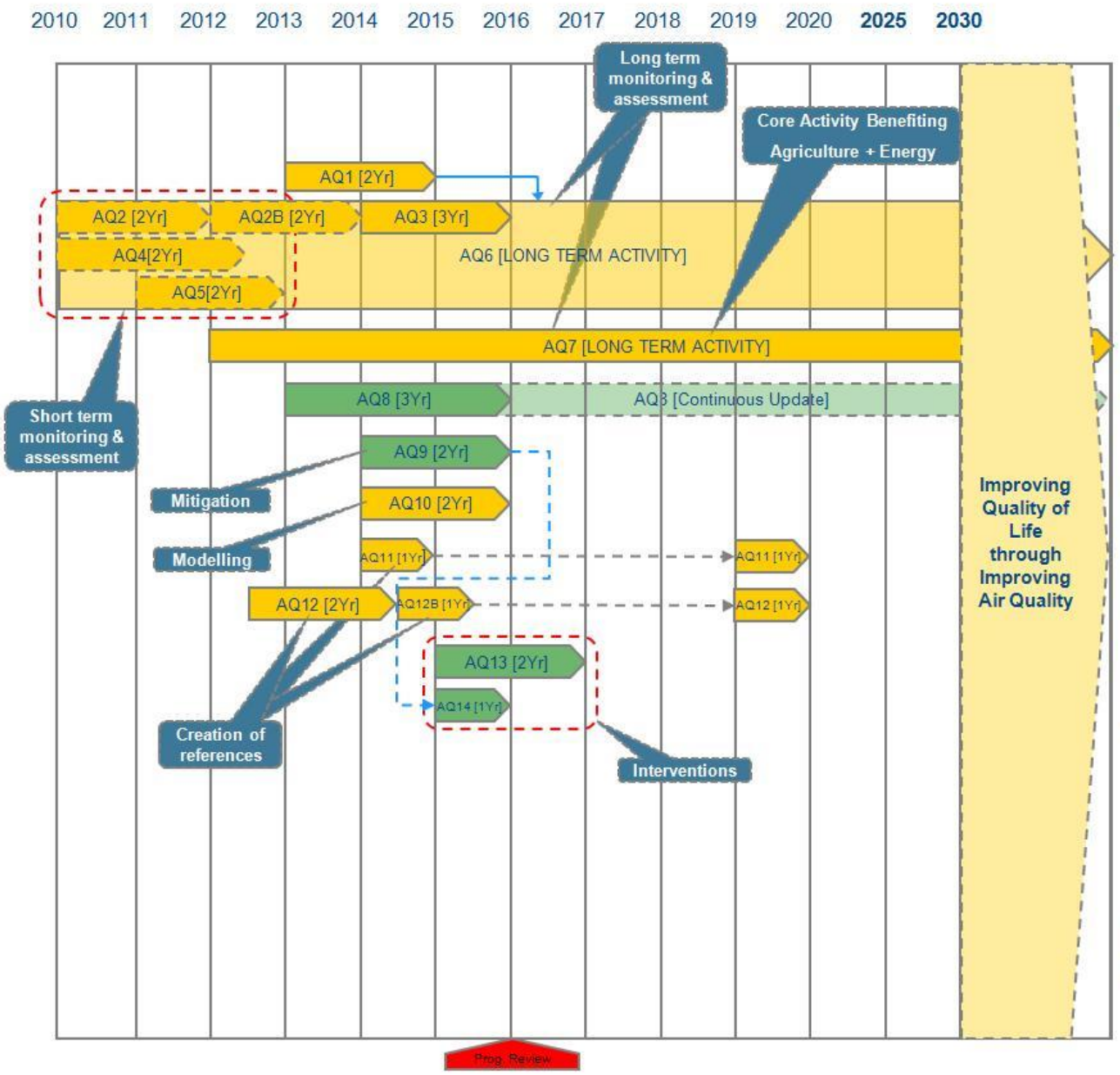
Maximum Volume of Accumulated Aeolian Sediment Around Native Plants



	Lycium Sp.	Nitraria Sp.	Haloxylon Sp.	Tamarix Sp.	Citrullus Sp.	Panicum Sp.	Calligonum Sp.	Rhanterium Sp.	Cyperus Sp.	Astragalus Sp.	Convolvulus Sp.	Salicornia Sp.	Heliotropium Sp.	Halocnemum Sp.	Arnebia Sp.
Minimum (m^3)	0.14	0.67	0.08	0.24	0.05	0.33	0.04	0.03	0.01	0.01	0.002	0.010	0.010	0.010	0.001
Average (m^3)	1.18	1.99	1.26	1.05	0.64	0.95	0.30	0.19	0.19	0.19	0.090	0.060	0.100	0.060	0.004
St. Deviation	1.30	1.33	1.21	0.59	0.45	0.46	0.35	0.24	0.21	0.13	0.120	0.090	0.080	0.050	0.002


Controlled mobile sand around plants in m3
10.00
1.00
0.10
0.01
125.00
25.00
5.00
1.00
0.20
0.04
The economic cost saved by plants (USD)
T. aphylla
Prosopis
Nitraria
Calligonum
Haloxylon
Panicum
Lycium
Convolvulus
Cyperus
Heliotropium
Rhanterium
Tamarix
Astragalus
Citrullus
Salicornia
Halocnemum
Arnebia



AQ1 - Develop a Tailor-Made Air Quality Monitoring & Data Collection System [KEPA's] with QC/QA Measures.

AQ2 - Monitoring & Assessment of Dust Fallout & Associated Pollen within the State of Kuwait (EC063C – KFAS).

AQ2B – Probability and Statistical Analysis of Total Suspended Particulates in Kuwait (EC082K – KFAS).

AQ3 – Allergenic Factors Associated with Airborne Dust in Kuwait.

AQ4 - Assessment of Indoor Organic Pollutants Level in Selected Schools and Hospitals (EC045C – KFAS).

AQ5 - Air Quality Assessment of Ali Sabah Al-Salem Urban Community Phase II (EC084C – KEPA)

AQ6 – Assessment of Air Quality Data.

AQ7 – Monitoring & Assessment of Meteorological Conditions [KNMN].

AQ8 – Developing a Comprehensive Emission Inventory.

AQ9 – Control/Reduction of Emission Levels to Meet Current KEPA Standards (VOCs, NOx & SOx, GHGs) [Options for Change].

AQ10 - Develop Recognised Numerical Models to Predict Pollutants' Dispersion Rates & Pollutants' Short-Long Range Fate in Kuwait.

AQ11 - Creating an Air Quality Baseline Atlas of Kuwait (Based on Collective Measurement & Modelling).

AQ12: Extreme Wind Atlas For Kuwait *(EC078C – KFAS)*

AQ12B - Creating the Meteorological Atlas of Kuwait.

AQ13 – AQ Impact of Master-Plan for Expansion of Power Generation, Water Des. & Petroleum-Related Activities.

AQ14 – Recommendation for Revising & Updating Kuwaiti Air Quality Regulations and Standards and Help in Developing Appropriate Legislations.

Applied Research
Policy


THANK YOU