Socioeconomic effect of dust storms in Kuwait

Ali Al-Hemoud, Mane Al-Sudairawi, Subramanian Neelamanai, Adel Naseeb & Weam Behbehani

Arabian Journal of Geosciences

ISSN 1866-7511
Volume 10
Number 1

Arab J Geosci (2017) 10:1-9
DOI 10.1007/s12517-016-2816-9

Springer

Arab J Geosci (2017) 10:18
DOI 10.1007/s12517-016-2816-9

ORIGINAL PAPER

Socioeconomic effect of dust storms in Kuwait

Ali Al-Hemoud[1] · Mane Al-Sudairawi[1] · Subramanian Neelamanai[2] · Adel Naseeb[3] · Weam Behbehani[3]

Received: 8 September 2016 / Accepted: 21 December 2016

Abstract Kuwait is an arid country with an annual average rainfall of about 110 to 120 mm. Hence, dust storms have become a common environmental crisis. Although the dry summer months commonly have more dust storms, in recent years, dust storms occur more frequently in the spring season as well. Accumulated data of dust storms in Kuwait for the past 14 years (2001–2014) showed that the month of March had the highest number of dust storms (total 19), which is rather unusual, with an average of 8 dust storms per year (year 2008 had the highest dust storms of total 22). This study explored four socioeconomic effects of dust storms in Kuwait, specifically traffic accident rates, oil export loss due to close out of marine terminals, airline delays due to airport operation shutdown, and agriculture degradation. Statistical analysis using *t* test and Pearson correlation showed no apparent relationship between dust storms and traffic accident rates or agricultural production; however, loss of oil export and flight delay cost were affected by dust storms. There has been very few published research on the socioeconomic impact of dust storms; this is the first paper that explores the detailed socioeconomic effect of dust storms in Kuwait.

✉ Ali Al-Hemoud
ahomood@kisr.edu.kw

[1] Crisis Decision Support Program, Environment and Life Sciences Research Center, Kuwait Institute for Scientific Research, P. O. Box 24885, 13109 Safat, Kuwait

[2] Coastal Management Program, Environment and Life Sciences Research Center, Kuwait Institute for Scientific Research, P. O. Box 24885, 13109 Safat, Kuwait

[3] Techno-Economics Division, Kuwait Institute for Scientific Research, P. O. Box 24885, 13109 Safat, Kuwait

Keywords Socioeconomic effect · Dust storms

Introduction

Sand and dust storms are lower atmosphere events that result from wind erosion liberating settlement particles from the ground surface; sand storms occur relatively close to the ground surface, but finer particles may be lifted kilometers high into the atmosphere (UNEP 2016). Dust storms are formally defined by the World Meteorological Organization (WMO 2005) as the results of surface winds raising large quantities of dust into the air and reducing visibility at eye level (1.8 m) to less than 1000 m (McTanish and Pitbaldo 1987). Airborne dust particles can be transported thousands of kilometers from their source region as an aeolian process encompassing emission, transport, and deposition of sand and dust (Kok et al. 2012; Goudie 2009). There are different numerical approaches to investigate physical modeling of dust storms including numerical analysis of dust storms in the form of density current as they are common in the Arabian Peninsula. Quantification of the actual shape of dust has been studied through application of fluid dynamics. Low-density pyroclastic currents that are mixtures of two components, namely, solid particles and fluid (gas) phase, behave as dense, multiphase gravity currents (Sulpizio et al. 2014). Dioguardi et al. (2014) introduced a new shape factor to quantify the actual shape of the dust and better predict gas-particle drag force.

Kuwait is one of the major countries with dust storms (Al-Hurban and Al-Ostad, 2010). It is located in the northwestern part of the Arabian Gulf and surrounded by Saudi Arabia and Iraq. Al-Dousari and Al-Awadhi (2012) identified five major source areas of dust for Kuwait which are the western desert of Iraq, the Mesopotamian flood plain, the northern desert of Saudi Arabia, the drained marshes in southern Iraq, and Iran.

Published online: 03 January 2017

Based on the depositional rates of dust fallout within the seven major dust storm trajectories in the world, Kuwait lies in zone IV, Northern Arabia, and is ranked second after zone I, the Western and Southern Sahara Desert. Along with the dust, other elements like bacteria, virus, pollens, pesticides, insecticide, and herbicide residues can also travel and are associated with increased risk of asthma admissions to hospitals in Kuwait (Thalib and Al-Taiar 2012; Abdal et al. 2010; Al-Thaiar and Thalib 2014) and respiratory health disorders worldwide (Goudie 2014, Karanasiou et al. 2012, Bennion et al. 2007).

One of the major effects of a dust storm is its ability to distort horizontal visibility. In a normal dust storm, visibility is around 1000 m; in a medium dust storm, it reduces to 200 m; and in a high dust storm, it reduces to zero visibility. Human-induced change is by far the most significant factor in the alarming increase of sand storms in some regions (Sivakumar 2005). Dust storms are considered as potential source of pollution in Kuwait (Al-Enezi et al. 2014) and reduce the horizontal visibility up to 1000 m, and depending on the wind conditions in a particular year, it may be reduced to even 250 m or less (Fig. 1). There is no fixed occurrence duration of the dust storms in Kuwait, but usually, the frequency increases during the summer months of May and June (Shalaby 2014). In recent years, dust storms occur more frequently in the spring season. Data collected for the past 14 years (2001–2014) showed that the month of March is characterized by the highest number of dust storms in Kuwait, which is rather unusual since the period running from the months of December to April is considered spring rainy season (Fig. 2a, b). Misak et al. (2014) presented the socio-economic impact of significant dust storm events in Kuwait that occurred unexpectedly during non-dusty seasons (Table 1). In a recent meteorological press conference, Ramadhan (2015) stated that the average number of dust storms in Kuwait is 137 days per year from 1968 to 2012 of which 58 days are considered as days with suspended dust, 63 days with rising dust, and 16 days with dusty storms. In addition, the average annual level of particulate matter with aerodynamic diameter of less than or equal to 10 μm of particulate matter PM10 and 2.5 μm of particulate matter of PM2.5 in Kuwait were 130 and 53 $\mu g/m^3$, respectively (Al-Olayan et al., 2013). These concentrations exceeded the annual World Health Organization's (WHO) guidance for outdoor air quality of 20 $\mu g/m^3$ for PM10 and 10 $\mu g/m^3$ for PM2.5 by a factor of six and five, respectively (Tsiouri et al. 2015). Al-Awadhi and AlShuaibi (2013) revealed that annual average deposition rate in Kuwait ranked the first out of 56 dust deposition rates observed throughout the world (0.59 kg/m^2/year). It is estimated that 4569 t of iron; 12,743 t of clay; 99,818 t of quartz; 14,177 t of sulfate; and 169,167 t of ash have fallen into Kuwait bay from August 2010 to July 2011. This shows the seriousness of the presence of high level particulate matter in the atmosphere of Kuwait.

Dust storms have negative impact on socioeconomic events in Kuwait including traffic accidents, sea port close-out, airport shutdown and flight delays, and agriculture degradation (Al-Hemoud and Neelamani, 2015). Very few published research has been published earlier to show the effect of dust storms on socioeconomics (Tozer and Leys 2013; Jeong 2008; Ai and Polenske 2008). Similarly, few research studies dealt with the relationship between dust storms and traffic accident rates (Mohammad 1989; Khalaf et al. 1988). The economic cost of traffic accidents is estimated to be between 1 and 3% of national income (Al-Naser 2003) and between 3 and 5% of gross domestic product (GDP) (Jamjoom 2003).

Dust storms can also have negative socioeconomic effects on the airline industry. Airline delay costs can be a substantial

Fig. 1 Dust storm over Kuwait city on March 25, 2011 (visibility close to zero, wind speed close to 50 km/h)

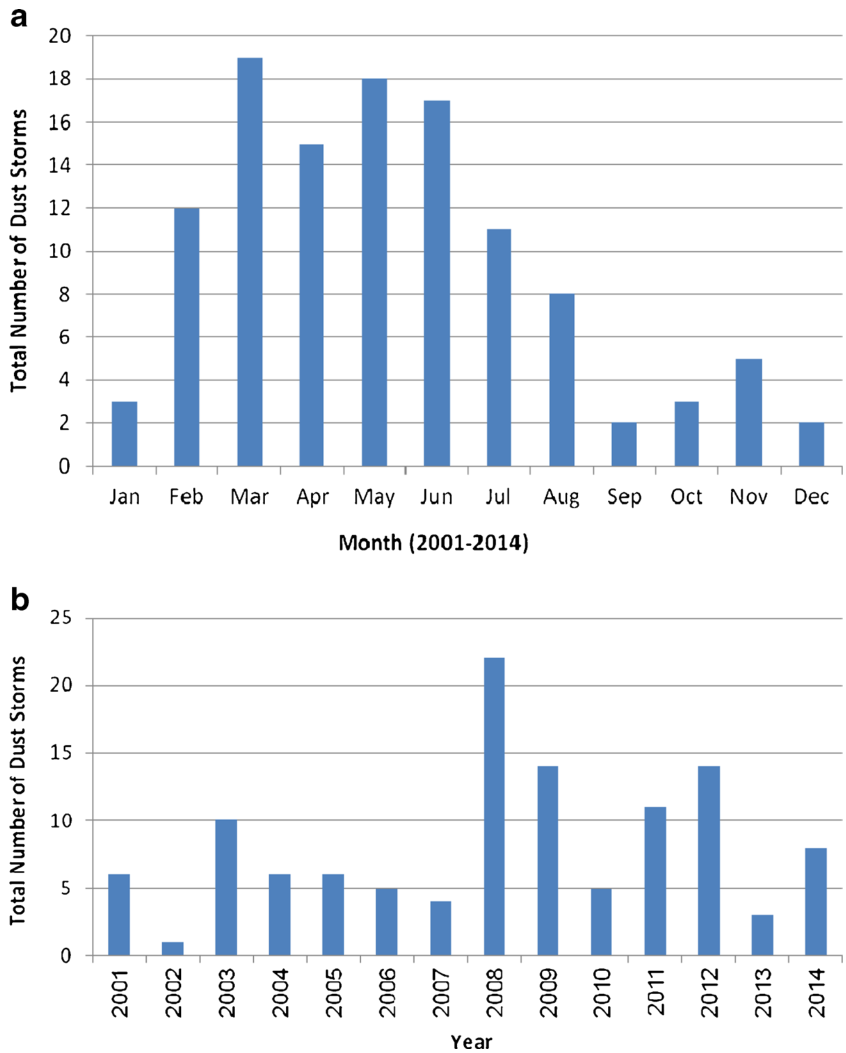


Fig. 2 **a** Total number of dust storms in Kuwait per month accumulated for the past 14 years (2001–2014). **b** Total number of dust storms in Kuwait (2001–2014)

contributor to an airline's costs (Eaton 2011). For example, during a dust storm called Red Dawn that passed the eastern side of New South Wales of Australia on 23 September 2009, which is considered to have seen the worst dust storm since the 1940s (Leys et al. 2011), visibility was reduced to 0.4 km affecting the air traffic daily activity (UNEP GEAS 2013), which resulted in a cost of A$299 million (Tozer and Leys 2013). Dust also causes damage for agriculture produce, especially if the plants are open to atmosphere (Ravi et al. 2011), and removal of organic matter and nutrient-rich lightest particles from the soil, thus reducing agricultural productivity (Akbari 2011; Stefanski and Sivakumar 2009). Dust storms have a significant socioeconomic loss on agriculture production by weakening soil stability to produce effectively (Munson et al. 2011). Moreover, dust storms decrease overall plant performance through their severe effect on photosynthesis (Ibrahim and El-Gaely, 2012). During dust transportation, many young plants are lost to the sand-blasting nature of the process at ground level, resulting in a loss of productivity (UNCCD 1999). According to the United Nations' Joint Analysis and Policy Unit (JAPU) report (2011), Kuwait is heavily affected by sand and dust storms, which would result in higher amount of annual GDP losses. Costs of delayed effects of sandstorms can be higher than those of the intermediate effects (Ai and Polenske 2008).

This study explored four socioeconomic effects of dust storms in Kuwait, specifically traffic accident rates, oil tankers and cargo ship delay at sea ports, airline delays due to airport operation shutdown, and agriculture degradation. To the best of our knowledge, the present paper is the first study that explores the socioeconomic effects of dust storms related to Kuwait, in detail.

Materials and methods

Data was collected from two sources: the first was the published data from the Kuwait Statistical Bureau and the second through four official correspondence letters sent by the Kuwait Institute for Scientific Research (KISR) requesting

Table 1 Record of significant dust storm events in Kuwait during non-dusty season

Date	Wind speed	Visibility (m)	Socioeconomic impact
11 April 2008	90 km/h		Semi-tornado, the violent wind uprooted hundreds of traffic signposts, billboards, and trees and damaged many cars in several parts of Kuwait, one killed and several wounded
10 March 2009	60 km/h	<150 m	A blinding dust storm hit Kuwait, halting oil exports and forcing the closure of all three ports besides disrupting air traffic. Incoming planes were facing difficulty landing.
25 March 2011	50 km/h	About zero	Mobile networks were jammed, and heavy traffic resulted because of poor visibility that plunged to almost zero. Fights were disrupted and the airport was shut down. While incoming flights were directed to other nearby airports, outgoing flights were canceled. Drivers had to slow down and stop as the sand turned skies into an orange-brown, enveloping the whole city.
4 April 2011	100 km/h	<50 m	Dust storm forced Kuwait airport to shut down for hours. Planes have been diverted to nearby airports and all departing planes have been grounded until the weather condition improved. Several ministries and offices have told their employees to go or stay at home until conditions get better. Four people are believed to have died during the sand storm.
12 February 2015	70 km/h	<100 m	Sudden afternoon dust storm occurred during a national festival which blew out the event chairs, tables, and tents. Oil exports at terminals at the three oil refineries have been halted and air flight canceled for 4 h.

information on socioeconomic factors related to dust storms from four local organizations, Kuwait General Traffic Department, Kuwait Port Authority, Directorate General of Civil Aviation, and Public Authority of Agriculture Affairs and Fish Resources. All four organizations responded positively and provided valuable data pertaining to dust storm effects on their related services and activities. The following paragraphs discuss the methodology used for the four socioeconomic effects of dust storms in Kuwait, namely, traffic accident rates, oil tankers and cargo ship delay at sea ports, airline delays due to airport operation shutdown, and agriculture degradation.

With regard to dust storms and their effect on traffic accidents, Pearson product-moment correlation coefficient 'r' was tested to determine the relationship between two variables (dust storms and traffic accidents). SPSS v. 16 statistical package was used for data analysis. A significance test for the correlation coefficient was carried out using a two-tailed correlation at the 0.01 level to determine whether any correlation exists between dust storms and traffic accidents. The null hypothesis (no correlation) was tested against the alternative hypothesis (strong correlation). Cost impact of dust storms on traffic accidents was based on KISR's study of Economic Cost of Traffic Accident Baseline model (Khalaf et al. 1988), which included direct costs (overall economic cost of all goods and services that are consumed as a result of car accidents) and indirect costs (cost of material consumption and loss of production) (Table 2). KISR's study estimated the total cost (direct and indirect) of all traffic accidents for the year 1984 to be 129,573,589 Kuwaiti Dinar (KD) (about US$431,911,963); this cost estimate was used as a baseline measure and interpolated by an average constant inflation rate of 3% for the years 2001 to 2014. This method of interpolation was chosen based on the following criteria: (1) traffic accidents increased by only 30% from 1984 to 2001 (23,642 vs. 31,028), which is considered relatively low accident rate increase during the last 17 years in relation to population growth during the same period; (2) indirect cost represents 86% of total traffic accident cost with human casualty representing 76% of total indirect cost. Moreover, during the selected period from 1984 to2014, the accident death rate was on a constant average of 300 deaths per year, indicating a steady indirect accident loss during the last 17 years.

In order to estimate oil export loss because of the shutdown of oil terminals and delay of oil tankers from entering the export berths due to sand storms, the average daily crude oil exports in million barrels and average prices for crude oil exports in US$ were collected from the Organization of the Petroleum Exporting Countries" (OPECs) annual statistical bulletin for the years 2001 to 2014 (OPEC 2014). Estimation of US$ loss of oil export was calculated using the following equation:

$$\text{Loss} = (\text{avg price} \times \text{avg export} \times \text{no . dust storms})/\text{no . oil tankers}$$

where loss is the loss of crude oil export due to sand storms per ship; avg. price is the average price for crude oil export ($/barrel); avg. export is the average daily crude oil export (number of barrels/year); no. dust storms is the number of dust storms per year; and no. oil tankers is the number of oil tankers cleared from oil terminals per year.

Cost of airline delay is calculated separately for strategic delays (those accounted for in advance) and tactical delay (those incurred on the day of operations and not accounted for in advance). In this study, only the tactical airline delay cost due to sand storms was calculated (Table 3). Kuwait's tactical airline delay cost was based on the total European cost of Air Traffic Flow Management's (ATFM) delay estimate values (Cook 2011). These airline delay cost estimates provide reference values for typical aviation delay costs for each

Table 2 Cost types of traffic accidents

Direct costs	Indirect costs
Property damages: • Repair costs and the replacement of vehicles • Costs of cargo and belonging lost • Costs of public properties and road structures, signs, traffic lights, etc. Personal: • Ambulance service costs to transport injured personnel • Medical costs (medical emergency care, hospital stay, medical treatment and surgical services costs, rehabilitation costs, medical aids and disability treatment costs) • Legal costs • Costs resulting from the use of alternative means of transportation	Police and security: accident investigation and reporting, first aid and medical assistance, directing traffic after accidents, law enforcement and court time Accident prevention: application of traffic laws, fulfillment of the necessary patrols to prevent accidents, technical inspection of vehicles, traffic awareness campaigns, training in traffic regulation and other administrative services Fire services costs Insurance costs Government subsidies Income cost: includes the present value of expected future income of the injured or deceased Psychological and social costs: loss of learning opportunities, addiction, loss of friendships and social relations

minute of primary delay during four flight phases: at-gate, taxi, cruise extension, and arrival management.

The value of agricultural production represents the added value to net agricultural production value by deducting input values of agricultural sector from output values evaluated by sale price (from receipt at farm sale price). Revenues and expenses of agricultural production (field and greenhouse crops) were aggregated for three rounds of local agricultural season (early summer, late summer, winter). Pearson product-moment correlation coefficient 'r' was tested to determine the relationship between agricultural production value and dust storms, while the t test was used to determine differences between mean production volume between field and greenhouse crops.

Results and discussion

Statistical analysis using Pearson product-moment correlation 'r' of traffic accident data from the Kuwait Traffic Department Annual Statistical Report (KTDASR 2014) showed that even though traffic accidents increased between 2001 and 2014, there was no direct relationship between total number of dust storms and total number of traffic accidents ('r = 0.129, p = .0.660) and between dust storms and traffic accident rates ($r = -0.107$, $p = 0.715$); two previous studies reported similar results (Mohammad 1989; Khalaf et al. 1988). Estimated cost of traffic accidents in Kuwait total to 262,806,234 KD (about US$78,841,870) for the year 2014; Table 4 presents the total cost of traffic accidents from year 2001 to 2014.

Since Kuwait is heavily dependent on oil exports for its revenue, it is important that ship transportation in Kuwait's bay operates without any delay to avoid huge economic

Table 3 Tactical delay cost of airlines

Phases of tactical delay costs:
1. At-gate (auxiliary power unit APU and engines off)
2. Taxi
3. En-route (cruise/route extension)
4. Arrival management (e.g., flow sequencing, stacking)

Overview of calculations:
1. Fuel—fuel costs and burn costs
2. Maintenance (factors such as 'mechanical' attrition of aircraft waiting at agates, subjected to arrival management, or accepting longer re-routes in order to obtain a better departure slot)
3. Crew (the flight and cabin crew marginal costs are based on the cost of crewing for additional minutes over and above those actually planned)
4. Passenger (hard costs such as passenger rebooking, compensation and care, and soft costs such as a passenger with flexible ticket)
5. Recreation (costs of 'knock-on' delay in the rest of the network on the day of operation)

Table 4 Estimated total cost of traffic accidents in Kuwait

Years	Dust storms[a]	Traffic accidents[a]	Estimated total costs[b] (KD)
2001	6	31,028	163,329,360
2002	1	37,650	164,780,460
2003	10	45,376	166,364,577
2004	6	54,878	168,441,746
2005	6	56,235	175,420,247
2006	5	60,410	180,782,867
2007	4	63,323	190,698,717
2008	22	56,660	210,879,809
2009	14	61,298	220,600,515
2010	5	65,861	230,519,603
2011	11	75,194	241,827,363
2012	14	86,542	249,564,251
2013	3	89,527	256,309,231
2014	8	99,047	262,806,234

[a] No direct relationship between total number of dust storms and total number of traffic accidents (Pearson correlation $r = 0.129$, $p = .0.660$

[b] Estimated total cost uses the 1984 baseline of direct and indirect cost (Khalaf et al., 1988)

Table 5 Estimated US$ loss of crude oil due to sand storms per ship in Kuwait

Year	Average daily crude oil production (barrels)	Average daily crude oil exports (barrels)	Average price for crude oil export ($/barrel)	Number of Oil tankers cleared from oil terminals	$US loss due to sand storms per ship
2001	1,947,000	1,214,100	21.37	1052	147,977
2002	1,745,900	1,138,000	23.61	1178	22,808
2003	2,107,600	1,242,900	26.89	1262	264,830
2004	2,288,700	1,414,900	34.08	1279	226,207
2005	2,573,400	1,650,800	48.66	1352	356,485
2006	2,664,500	1,723,400	58.88	1355	374,442
2007	2,574,500	1,612,900	66.35	1048	408,458
2008	2,676,000	1,738,500	91.16	1002	3,479,637
2009	2,261,600	1,348,000	60.68	1370	835.878
2010	2,312,100	1,430,000	76.32	1424	383,208
2011	2,658,700	1,816,000	105.63	1479	1,426,683
2012	2,977,600	2,070,000	108.93	1469	2,148,939
2013	2,924,700	2,058,000	105.04	1475	439,673
2014	2,866,800	1,995,000	95.32	1484	1,025,140

losses. Kuwait is the fourth largest OPEC member with an average daily crude oil production of 2,866,800 barrels in 2014, 70% of which (1,995,000 barrels) is exported as crude oil daily through the Kuwait National Petroleum Company's (KNPC's) three export facilities (Al-Shuaiba, Al-Ahmadi, Abdullah). During dust storms when visibility is low, crude oil export is halted in all three terminals, and oil tankers remain outside the berths in the sea costing the country over US$1 million in 2014 (8 dust storms) and close to US$3.5 million in 2008 (22 dust storms) (see Table 5).

Fig. 4 The effect of dust storm on horizontal visibility in high-velocity winds on airplanes

Total number of aircrafts in-bound and out-bound of Kuwait has been increasing linearly from 2001 to 2014 (Fig. 3). One of the major problems that any international airport faces is flight delays due to external environmental events such as dust storms. This is a major problem for airline industry because it will delay aircrafts from departure, thus forcing more ground time that is translated into cost for the airline. In Kuwait, winds of up to 45 km per hour reduce visibility to less than 150 m at Kuwait airport and much less in the open desert (Fig. 4). During dust storms, Kuwait Civil Aviation Authority reschedules all flights (landing and take-off); landing flights will be diverted to neighboring countries, while departing flights will be halted until weather conditions improve, as assured by the control tower. This assurance could come after a period of 1 h to 1 day depending on the density of dust storms. Tactical delay costs are used as indicators and insights into delay and are incurred on the day of operations.

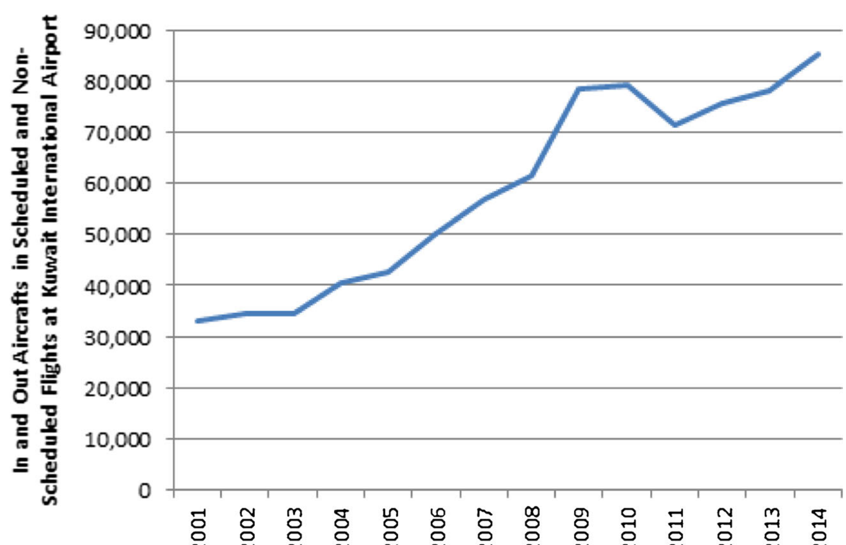


Fig. 3 Total number of aircrafts at Kuwait International Airport (2001–2014)

Table 6 Air Traffic Flow Management (ATFM) delay cost estimates (in Euro) in Europe and Kuwait

Factor	Europe	Kuwait
Network total cost of ATFM delay (all causes)	1250 million	–
Average cost delay of an ATFM delayed aircraft	1660	830
Network average cost of ATFM delay, per minute	81	40

The total European cost of Air Traffic Flow Management (ATFM) delay is estimated as EUR 1250 million, and the average cost of delay of an ATFM delayed flight is EUR 1660, which equates to a value of EUR 81 per minute (Cook, 2011). For Kuwait, it is assumed that ATFM's tactical delay cost is 50% lower than Europe's ATFM's delay cost due to the following reasons: lower fuel prices, lower cabin crew salaries, lower maintenance costs, and lower recreation costs. Since Kuwait airport has the ability to contain about 30 planes at the same time, the daily tactical airline cost was estimated to be EUR 24,900 (9725 KD) (Table 6).

Table 7 presents the estimated agriculture production value in Kuwaiti Dinar (KD) from field crops and greenhouses. Statistical data analysis revealed weak correlation between the number of dust storms and agriculture production value (Pearson correlation $r = -0.135$, $p = 0.710$). As can be seen from the table, filed crop production value represents roughly 65% of grand total production value. Figure 5 shows total plant production (in tons) for both field and greenhouses. Field crops are grown in only two seasons in Kuwait, summer and winter; summer crops represent 22% of total production, while winter crops represent the remaining 78%. Greenhouse crops represent only 16% of the grand total crops while 84% of crops are planted in open fields. Over the past 10 years, agriculture production loss (in tons) has been shown to be insignificant due to the expansion of agriculture land holdings, newly invented systems for water irrigation, and modern utilization of greenhouses; however, a significant increase in filed crop production versus greenhouse was shown using statistical *t* test of means ($t = 12.414$, df = 9, $p < 0.01$).

Conclusions

Dust storms have wide-ranging economic impacts, both immediate and long term. Long-term impacts of dust storms are less documented than are immediate impacts. The impact of dust storms on national and regional economies cannot be overestimated. Due to the complexity of how dust storms impact various socioeconomic sectors to different extents, few data regarding economic losses is available. The UN JAPU (2011) study suggested that increased dust storms would result in annual losses of US$12.7 billion in GDP per annum in the Middle East and North Africa (MENA) region alone; considering that Iraq, Iran, Kuwait, Saudi Arabia, Syria, Jordan, and Turkey as a subregion are more heavily affected by dust storms than the MENA is, the amount of annual GDP losses must be significantly higher.

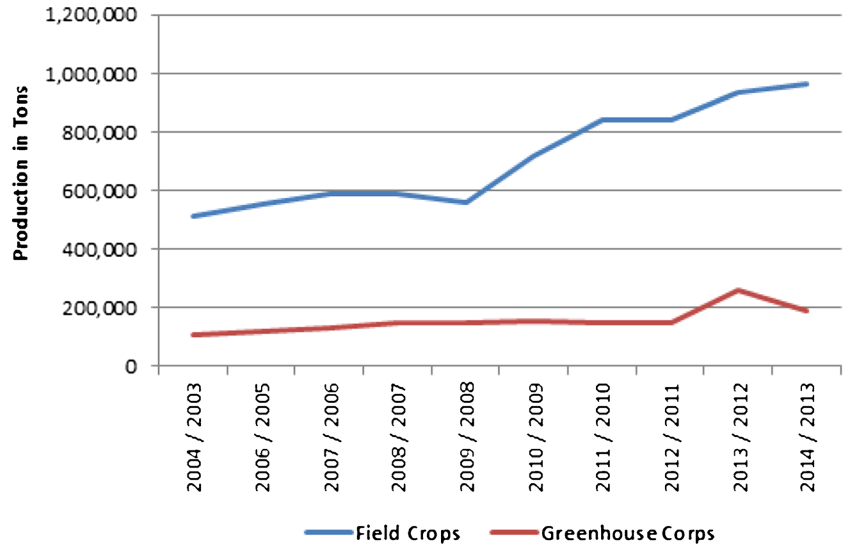
Dust storms have negative impact on socioeconomic events in Kuwait including traffic accidents, sea port close-out, airport shutdown and flight delays, and agriculture degradation. No direct relationship was determined between dust storms and traffic accidents (weak correlation, $r = 0.354$); a similar study reached the same conclusion (Mohammad, 1989). Traffic accidents in Kuwait were mostly related to drivers' behavior rather than to environmental or social factors (Al-Hemoud, et al., 2010). Annual economic cost estimate of traffic accidents in Kuwait was about $340 million (Al-Mutair 2006) and amounts to 2% of GDP (El-Raey 2006).

Sea-port officials stated that dust storms affect marine traffic, causing serious problems and precluding ships from maneuvering at Kuwait's bay. Average number of oil tankers

Table 7 Estimated crop production value from field and greenhouses

Year	Crop Production Value in KD		Grand total production value KD
	Field crops	Greenhouse crops	
2004/2003	20,552,745.00	10,143,098.00	30,695,843.00
2006/2005	24,023,737.00	11,464,234.00	35,487,971.00
2007/2006	25,306,581.00	12,105,008.00	37,411,589.00
2008/2007	24,598,430.00	13,912,957.00	38,511,387.00
2009/2008	24,661,915.00	14,151,341.00	38,813,256.00
2010/2009	29,590,284.00	14,835,047.00	44,425,331.00
2011/2010	44,007,540.50	18,439,298.86	62,446,839.36
2012/2011	41,807,285.50	17,952,208.36	59,759,493.86
2013/2012	49,500,497.70	29,455,515.35	78,956,013.05
2014/2013	56,706,343.80	32,006,638.25	88,712,982.05

Fig. 5 Estimated plant production from field and greenhouses crops



cleared from Kuwait's ports is estimated to be 1300 with daily price for total crude oil export estimated to be US$114 million. Delays from the dust storms will affect the country's revenues leading to a reduction in oil export and therefore have a negative effect on inflation.

Kuwait's flight delay tactical cost was assumed to be twice as the European flight delay tactical cost. Furthermore, dust storms affect the work productivity of airlines such as air ground traffic and bagged transportation, which leads to a negative effect on the GDP by 0.1% in the Arab countries.

Weak correlation was shown between dust storms and agriculture production in Kuwait. With an average number of 8 dust storms per year during the last 14 years, it was noticed that the annual total crop production increased from around 500,000 to 900,000 t, while total sales also increased from around 30 million to 88 million KD during the same period.

Acknowledgements The authors are grateful to the Kuwait Institute tor Scientific Research (KISR) and the Kuwait Foundation for the Advancement of Sciences (KFAS) for financing this study through the grant 2012-4401-0l.

References

Abdal AT, Ayed A, Nair PC, Mosawi M, Behbehani N (2010) Factors responsible for asthma and rhinitis among Kuwaiti schoolchildren. Med Princ Pract 19:295–229

Ai N, Polenske KR (2008) Socioeconomic impact analysis of yellow-dust storms: an approach and case study for Beijing. Econ Syst Res 20(2):187–203

Akbari S (2011) Dust storms, sources in the Middle East and economic model for survey its impacts. Aust J Basic Appl Sci 5(12):227–233

Al-Awadhi JM, AlShuaibi A (2013) Dust fallout in Kuwait city: deposition and characterization. Sci Total Environ 461:139–148

Al-Dousari AM, Al-Awadhi J (2012) Dust fallout in the northern Kuwait, major sources and characteristics. Kuwait J Sci 39(2A):171–187

Al-Enezi E, Al-Dousari AM, Al-Shammari F (2014) Modeling adsorption of inorganic phosphorus on dust fallout in Kuwait bay. J Eng Res 2(2):1–14

Al-Hemoud A, Neelamani S (2015). Techno economic effect of dust storm in Kuwait. Tamilnadu Engineers Forum (TEF) Conference in Kuwait

Al-Hemoud A, Simmons R, Al-Asfoor M (2010) Behavior and lifestyle characteristics of male Kuwaiti drivers. J Saf Res 41(4):307–313

Al-Hurban AE, Al-Ostad AN (2010) Textural characteristics of dust fall-out and potential effect on public health in Kuwait City and suburbs. Environl Earth Sci 60:169–181

Al-Mutair A (2006) Car accidents in Arab countries: risks and economic cost estimation. In: Naif Arab University for Security Sciences (NAUSS). Saudi Arabia, Riyadh

Al-Naser FA (2003) Psychological dimensions road traffic accidents. In: Naif Arab University for Security Sciences (NAUSS). Saudi Arabia, Riyadh

Al-Olayan MA, Brown KW, Evans JS, Bouhamra WS, Koutrakis P (2013) Source apportionment of fine particles in Kuwait City. Sci Total Environ 448:14–25

Al-Taiar A, Thalib L (2014) Short-term effect of dust storms on the risk of mortality due to respiratory, cardiovascular and all-causes in Kuwait. Int J Biometeorol 58(1):69–77

Bennion P, Hubbard R, O'Hara S, Wiggs G, Wegerdt J, Lewis S, Small I, van der Meer J, Upshur R (2007) The impact of airborne dust on respiratory health in children living in the Aral Sea region. Int J Epidemiol 36(5):1103–1110

Cook A (2011) European airline delay cost reference values. Department of Transport Studies, University of Westminster, London, UK, pp 29–32

Dioguardi F, Dellino P, Mele D (2014) Integration of a new shape-dependent particle-fluid drag coefficient law in the multiphase Eulerian–Lagrangian code MFIX-DEM. Powder Technol 260:68–77

Eaton G (2011) Measuring airline operating and delay costs. ACI-NA 20TH Annual Conference and Exhibition, San Diego, CA, October 16–19

El-Raey M (2006) Air quality and atmospheric pollution in the Arab region. UNEP (United Nation Environment Programme) and Regional Office for West Asia. West Asia Report.

Goudie AS (2009) Dust storms: recent developments. J Environ Manag 90:89–94

Goudie AS (2014) Desert dust and human health disorders. Environ Int 63:101–113

Ibrahim M, El-Gaely G (2012) Short-term effects of dust storm on physiological performance of some wild plants in Riyadh, Saudi Arabia. Afr J Agric Res 7(47):6305–6312

Jamjoom A (2003) Traffic awareness and its impact on reducing traffic accidents. Naif Arab University for Security Sciences (NAUSS). Saudi Arabia, Riyadh

Jeong D (2008) Socio-economic costs from yellow dust damages in South Korea. Korean Soc Sci J 2:1–29

Karanasiou A, Moreno N, Moreno T, Viana M, de Leeuw F, Querol X (2012) Health effects from Sahara dust episodes in Europe: literature review and research gaps. Environ Int 47:107–114

Khalaf B, Abdul-Halim M, Al-Qudsi S, Al-Shatti A, Jafaar F (1988) An economic analysis of car accidents: profiles, causes and impacts. Final Report, Kuwait Institute for Scientific Research (KISR) report no. 2531

Kok JF, Parteli EJ, Michaels TI, Karam DB (2012) The physics of wind-blown sand and dust. Rep Prog Phys 75:1–72

Kuwait Traffic Department Annual Statistical Report (TDASR) (2014) Traffic accidents and traffic violations statistics (2001–2014)

Leys J, Heidenreich SK, Strong CL, McTanish GH, Quigley S (2011) PM10 concentrations and mass transport during "red Dawn"—Sydney 23 September 2009. Aeolian Res 3:327–342

McTainish GH, Pitbaldo JR (1987) Dust storms and related phenomena measured from meteorological records in Australia. Earth Surf Process Landf 12:415–424

Misak R, Al-Enezi A, Al-Sudairawi M (2014). Characterization and prioritization of hazards in Kuwait. Concept Note, Kuwait Institute for Scientific Research (KISR)

Mohammad MA (1989) Dust storm phenomena and their environmental impacts in Kuwait. PhD thesis, University of Glasgow, UK. pp. 138–142

Munson SM, Belnap J, Reynolds R (2011) Science features: dust storms roll across Arizona—*USGS Science Explains the Phenomenon.*

Organization of the Petroleum Exporting Countries (OPEC 2014) Annual Statistical Bulletin (2001-2014). Austria, Vienna

Ramadhan E (2015) Green belt in the northwest of Kuwait as a method of dust storm reduction. Kuwait News Agency Press Conference

Ravi S, D'Odorico P, Breshears DD, Field JP, Goudie AS, Huxman TE, Li L, Okin GS, Swap RJ, Thomas AD, Pelt SV, Whiicker JJ, Zobeck TM (2011) Aeolian process and the biosphere. Rev Geophys 49:1–45

Sivakumar MV (2005) Natural disasters and extreme events in agriculture: impacts and mitigation. Chapter 10: Impacts of Sand Storms/ Dust Storms on Agriculture, Springer Berlin Heidelberg Publisher 159–177

Stefanski R, Sivakumar M (2009) Impacts of sand and dust storms on agriculture and potential agricultural applications of a SDSWS. IOP Conference Series: Earth and Environ Sci 7(1):1–5

Shalaby A (2014). Severe dust storms over the Arabian Peninsula: observations and modeling. Geophysical Research Abstracts 15

Sulpizio R, Dellino P, Doronzo D, Sarocchi D (2014) Pyroclastic density currents: state of the art and perspectives. J Volcanol Geotherm Res 283:36–65

Thalib L, Al-Taiar A (2012) Dust storms and the risk of asthma admissions to hospitals in Kuwait. Sci Total Environ 433:347–351

Tozer P, Leys J (2013) Dust storms—what do they really cost? The Rangeland J 35(2):131–142

Tsiouri V, Kakosimos KE, Kumar P (2015) Concentrations, sources and exposure risks associated with particulate matter in the Middle East area—a review. Air Quality, Atmosphere & Health 8(1):67–80

UNEP Global Environmental Alert Service (GEAS) (2013). Forecasting early warning of dust storms

United Nations Joint Analysis and Policy Unit (JAPU) (2011). Sands and dust storms fact sheets

United Nations Convention to Combat Desertification (UNCCD) (1999). Global alarm: sand and dust storms from the world's drylands

UNEP, WMO, UNCCD (2016) Global assessment of sand and dust storms. United Nations Environment Programme, Nairobi

World Meteorological Organization (WMO) (2005) Climate change and land degradation WMO—No 989 .WMO, Geneva