Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
The immediate impact of the associated COVID-19’s lockdown campaign on the native vegetation recovery of Wadi Al Batin Tri-state desert

Zahraa M. Al-Ali, Meshal M. Abdullah, Amjad A. Assi, Mansour S. Alhumimidi, Al-Qurnawi S. Wasan, Thamer S. Ali

Abstract

1. Introduction

The coronavirus (COVID-19) is considered a novel pandemic that has spread worldwide. Consequently, the lockdown and stay-at-home campaign had an impact on the global health, global economy, societies, and environment (Buheji et al., 2020; Corlett et al., 2020; El Zowalaty et al., 2020; Leal Filho et al., 2020). The virus first appeared in December 2019 and rapidly spread across the whole world (Mandal and Pal 2020). Therefore, on March 11, 2020, the World Health Organization (WHO) announced that the COVID-19 is an on-going global pandemic and serious actions need to be taken. The actions are differed between the countries according to the intensity and number of infections (Cucinotta and Vanelli 2020). Around ten million cases with 503,862 deaths around the world were reported in June 2020 (WHO 2020). Due to the rapid spread of the virus, several countries developed and implemented a lockdown campaign that included: a full lockdown, enforced partial lockdowns, and conducted massive media awareness campaigns.

Several recent studies have studied the negative/positive impacts of...
COVID-19 lockdown campaigns on the environment (Corlett et al., 2020; El Zowalaty et al., 2020). The enhancement in air quality in many countries is a good example of the positive environmental changes. It was found that the air quality in many cities around the world has improved during the pandemic as a result of the restriction of human activities, such as transportation, industries, and tourism (Baldasano 2020; Berman and Ebisu 2020; Chen et al., 2020; Nakada and Urban, 2020; Sharma et al., 2020; Zambrano-Monserrate et al., 2020). Also, the lockdown of stone quarrying in India caused a decrease in the land surface temperature by 3–5 °C and in the noise level <65dBA (Mandal and Pal 2020). It was also indicated that the business and industrial wastes are significantly decreased in most countries due to the lockdown orders (Van Fan et al., 2020). However, some studies pointed out the negative impact of utilizing plastic facemasks on the environment, as it is considered an undegradable material (Fadare and Okofo 2020; Prata et al., 2020).

The 2020 sustainable development report indicated the impact of COVID-19 on SDGs (Sachs et al., 2020). It was found that many SDGs were influenced by the COVID-19, such as zero hunger, clean water and sanitation, affordable and clean energy, and sustainable cities and communities. However, the impact of COVID-19 on climate action, life underwater, and life on land are still unclear.

The effect of anthropogenic activities is significantly impacting natural arid ecosystems. Desertification and soil compaction are dramatically affecting these ecosystems, leading to severe losses in ecosystem services (Verón et al., 2018). As a result of these activities, natural ecosystems are becoming more degraded, as well as, the ability of the ecosystem to continue providing the quality and quantity of ecosystem services for human well-being is harmfully affected (Xu 2018; Halmy 2019). In the desert ecosystem, the growth of desert native vegetation is significantly impacted by anthropogenic activities and climate conditions. The harsh environment in arid regions makes the anthropogenic activities (quarrying, overgrazing, destructive camping, and off-road vehicle movements) have a significant impact on the growth of desert native vegetation (Zhu et al., 2018).

Remotely-sensed imagery is becoming a widely used technology in answering critical ecological questions. Advanced Remote Sensing (RS) technologies can play a significant role in providing a synoptic view of vast territories and extracting accurate information rapidly and continuously, with an acceptable cost-effectiveness analysis. According to previous studies, RS can generate a significant amount of information needed to evaluate the distribution of vegetation cover and monitoring desertification in arid and semi-arid ecosystems (Harris et al., 2014; Abdullah et al., 2021). The Normalized Difference Vegetation Index (NDVI) is a widely used RS method to evaluate vegetation and measure the amount of photosynthesis in semi-arid lands (Gui et al., 2013).

Thus, setting up the preventive roles, establishing media awareness campaigns, and enforcing the roles are the key elements of an effective mitigation plan to protect the vulnerable desert ecosystem. Those key elements were available during the COVID-19 lockdown campaign making the COVID-19 pandemics period a great opportunity for a real demo of an effective mitigation plan of anthropogenic activities on desert native vegetation systems. The present study aims to assess the impact of setting up actions during the COVID-19 in Kuwait, Saudi Arabia and Iraq on native desert vegetation in arid ecosystems represented by Wadi Al-Batin desert using remote sensing technologies.

2. Materials and methods

2.1. Study area

The study was conducted at Wadi Al-Batin desert ecosystems, covering a part of the Arabian Peninsula, with a total area of 68,832 km² (Fig. 1). The study area includes the Southwestern part of Iraq (IRQ) (25,219 km²), State of Kuwait (KUW) (17,435 km²), and Northeastern part of Saudi Arabia (KSA) (26,178 km²). The main characteristics of these lands are flat topography with small relief, scarcity and scanty rainfall (<126 mm), and high temperatures during the summer season (>45 °C), and cold during the winter season (<10 °C) (Nasrallah et al., 2004; Almazroui et al., 2012; Shubbar et al., 2017). The rainy season starts from October to May, with an average annual rainfall of 126 mm in KSA (Hasaneen and Almazroui 2015), 118 mm in Kuwait (Bannari and Al-Ali 2020), and 100 mm in Iraq (Hadeel et al., 2009). The main geomorphological feature at these lands is Wadi Al-Batin desert, which extends from KSA (Hafer Al-Batin) to the boundary between KUW and IRQ (Al-Sulaimi and Pitty 1995). Soils associated with the study area are mostly sandy characterized by limited nutrients and organic matter.

The study area is mainly considered an open desert with scattered desert plants, which are heavily disturbed by anthropogenic activities such as quarrying, overgrazing, destructive camping, off-road vehicle movements, and military operations (Wars) (Al-Awadhi et al., 2005; Khalaf et al., 2013; Assaeed et al., 2019).

2.2. Overall methodology

The overall methodology implemented is summarized in the methodological flowchart shown in Fig. 2. Remotely sensed data were utilized to investigate the indirect impact of COVID-19 on desert vegetation. The spectral vegetation index was applied over imageries during the period 2017 to 2020 to detect the changes in vegetation coverage. Furthermore, rainfall was considered in the analysis to determine rainfall intensity and frequency on yearly basis. This is important since native desert vegetation is highly influenced by rainfall fluctuation. Thus, it is essential to compare the COVID-19 year with short period previous years in terms of rainfall events to understand the pandemic’s impacts on native vegetation.

2.3. Data Collection

2.3.1. Rainfall data

Anthropogenic activities and rainfall are the two major factors affecting the growth of native vegetation in the area. Thus, similar rainy seasons should produce a relatively similar vegetation coverage. Moreover, the COVID-19 lockdown affected only the anthropogenic

![Fig. 1. Wadi Al-Batin Tri-State Desert Quadrangle (Sentinel-2A images-2020).](image-url)
activities. Therefore, comparing the vegetation coverage of the study area in the COVID-19 year with other rainy years of similar trend will reveal mainly the impact of anthropogenic activities on the vegetation growth and coverage.

In this study, the rainfall data for the period extended from 2017 to 2020 were obtained from seven meteorological stations, including two stations in IRQ (Abu Al Khaseeb and Salman), four stations in KUW (Kuwait Airport, Al-Abdali, Al-Wafra, and Al-Salmi), and one station in KSA (Al-Qaysumah). The annual rainfall was estimated based on the Thiessen polygon method using ArcMap 10.7.1 software. The station weight was calculated in each related Thiessen polygon, then multiplied by the station rainfall data and summed to obtain the average rainfall.

### 2.3.2. Satellite imageries

Nine Sentinel-2A satellite imageries were installed to cover the study area for one month. A total of 180 imageries were obtained monthly from the Copernicus Open Access Hub from 2017 to 2020 (S 1). All acquired imageries are free of clouds as falls within the vegetation growing season, which starts from January to May. Sentinel-2A satellite was launched in 2015 as part of the European Space Agency’s Copernicus Programme. This multispectral satellite was designed for global terrestrial observation, which provides free access, 12 spectral bands, four bands high resolution (10 m), and five days geometric revisit as presented in Table 1 (Drusch et al., 2012). These unique features are suitable for vegetation monitoring studies (Bhatnagar et al., 2020; Segarra et al., 2020).

#### 2.4. Satellite imageries data processing - vegetation coverage

The visible bands such as blue (B), green (G), and red (R), as well as Near Infra-Red (NIR), were stacked together for each image. These VNIR bands provided 10 m spatial resolution (pixel size), offering more precise information than other free satellite data such as Landsat (30 m). For change detection and classification methods, atmospheric correction is not always necessary because all images were individually classified using a spectral index, followed by estimating the percentage of vegetation coverage to detect vegetation changes in the same area (Foody et al., 1996; Song et al., 2001; Abdullah et al., 2017). Normalized Difference Vegetation Index (NDVI) was applied to all images to detect the changes in vegetation coverage. This index has relied on the combination of two spectral bands, including the red and NIR bands, where the red band is absorbed by chlorophyll and scattered by spongy mesophyll in the NIR band (Rouse 1973; Bamari et al., 1995; Huete et al., 2002). Indeed, this index exhibited acceptable results in arid regions where the vegetation is scattered and tiny (Abdullah et al., 2020; Al-Ali et al., 2020). ENVI (Harris Geospatial Solutions, Boulder, CO, 5.3) software was utilized to apply the vegetation index to each image separately, as shown in equation (1).

\[
NDVI = \frac{NIR(B8) - R(B4)}{NIR(B8) + R(B4)}
\]

Where:
- NIR: Near Infra-Red spectral band.
- R: Red spectral band.
- B4–B8: bands labels.

Afterward, the vegetation coverage layer was extracted from the land-use layer to distinguish between native desert vegetation and agricultural-urban vegetation (Fig. 3). The protected areas were extracted from open areas to focus on the direct impact of anthropogenic activities on native desert vegetation. The protected areas are represented by the nature reserve areas and any fenced areas that are difficult to enter, including the demilitarized zone, oil field areas, and military areas. The vegetation coverage was calculated based on the NDVI index by multiplying the counted pixels by the pixel size of sentinel imageries (10 m × 10 m), then converted to a percentage (%) based on the total area for each class. These steps were implemented in ArcMap 10.7.1 (ESRI, Redlands, CA, 10.7) software using the Spatial Analyst tool.
The spatial distribution of vegetation coverage significantly differed between the examined years (2017–2020) at Wadi Al Batin Tri-state Desert, as shown in Fig. 4. Based on the NDVI analysis, it was found that the highest vegetation coverage occurred in 2019, which is considered as a wet year, covering 60% of the study area. However, the COVID-19 year (2020), 2017, and 2018 are considered as drought years. But the COVID-19 year showed a noticeable higher vegetation coverage (28.5%) compared with the years 2017 (6%) and 2018 (2%).

Such variation in vegetation coverage between the examined years are more likely related to the rainfall fluctuation including the rainy months, rainfall amount, and frequencies, which significantly influences the vegetation coverage variation on yearly and monthly basis. In such desert ecosystem, high vegetation coverage can be detected during the growing season from January to March, and then it starts to slightly decrease in April and May due to the increase in temperature synchronized by a decrease in rainfall (Fig. 3A).

It was found that the years 2017, 2018, and the COVID-19 year are considered drought seasons with total rainfall of 60 mm, 65 mm, and 92 mm, respectively. However, the year 2019 was considered a wet year with high rainfall average (199.5 mm), resulting in high vegetation coverage. Therefore, the year 2019 was excluded, and the vegetation coverage of the COVID-19 year was only compared with the years 2017 and 2018 as they showed more or less variation in rainfall average.

It was clearly observed that the vegetation coverage obviously increased during the COVID-19 year, estimated by 29% (Fig. 5B). However, the years 2017 and 2018, which characterized by similar rainfall average, showed a meager vegetation coverage, which were 6% in 2017 and 2% in 2018, providing clear evidence that desert plants significantly increased during the COVID-19 year. The comparison between the COVID-19 year (2020) with both 2017 and 2018 indicated an increase in vegetation cover by 23% and 27%, respectively. Such increase could be attributed to the elimination of anthropogenic activities in the study area.

### 3.2. Spatiotemporal changes in vegetation coverage by state

The spatiotemporal variations in the vegetation coverage was also recognized among the three countries within Wadi Al-Batin tristate desert. It was observed that 54.1% of vegetation coverage during the COVID-19 year was detected in IRQ, almost similar to the rainy years in 2019, which reached 69.4% (Fig. 6). The high vegetation coverage in IRQ during the pandemic could be associated with the high rainfall events in most parts of the country with a total rainfall of 133 mm compared with the years 2017 and 2018, which were 7.3% coverage with a rainfall of 57 mm in 2017 and 2.5% coverage with a rainfall of 62 mm in 2018.

Subsequently, KUW and KSA received very low rainfall averages during the pandemic, which were similar to the drought years in 2017 and 2018, however the vegetation coverage was considerably increased in KUW and KSA during the COVID-19 year. It was found that the vegetation coverage in KUW covered 11.5% of the total vegetation coverage during the pandemic with a rainfall of 91 mm, which was higher than the vegetation coverage in 2017 (5.2% vegetation coverage with a rainfall of 83 mm) and 2018 (1.6% vegetation coverage, with a rainfall of 86 mm) as presented in Figure (6). Similar trend was found in KSA for the vegetation coverage during the pandemic (covered 11.5% of the full vegetation coverage), which was also higher than the year 2017 (4.3% vegetation coverage with a rainfall of 48 mm) and the year 2018 (0.7% vegetation with a rainfall of 54 mm) (Fig. 6).

### 3.3. Impact of anthropogenic activities during COVID-19 pandemic: open area vs protected area

The native desert plants were compared between protected areas and open deserts in order to point out the direct impact of anthropogenic activities in open areas. Among the three countries, the protected areas are only existed in the KUW and KSA, including nature reserves, oil fields (fenced areas), and demilitarized zones (KUW and KSA). Substantial differences at between the COVID-19 year and similar drought years (2017 and 2018) were determined both protected and open areas, illustrating that the COVID-19 year is an exceptional year where native vegetation was higher than in previous years with less rainfall variations at both protected and open areas. It was found that during the COVID-19 years, both areas presented the same percentage coverage of vegetation, which estimated to be 29% in the protected areas and 28.5% in the open areas (Fig. 7). Such increase seems to be considerable in comparison with previous years receiving the more or less similar trend of rainfall where the vegetation coverage found to be less than 10% in the year 2017 and 2018 at both protected and open areas as illustrated in Figure (7).

### 4. Discussions

This work provides clear evidence that the anthropogenic activities are impacting native desert vegetation. Based on the NDVI results, noticeable increase in vegetation coverage was found during the COVID-19 period. It was illustrated that most of the changes occurred in the open areas, potentially impacted by anthropogenic activities. These findings demonstrate that the lockdown due to COVID-19 minimizes negative impacts generated by anthropogenic activities, resulting in an obvious recovery of native desert plants. Although, the rainfall average during the COVID-19 period was low and considered as a drought season, the native desert vegetation can recover rapidly under such drought seasons as soon as the source of disturbance is largely limited. Moreover, the vegetation coverage in protected areas is previously exposed to illegal entry for grazing or other purposes. For instance, Kuwait EPA announced that they would start to implement the harshest penalties for any encroachment on nature reserves in order to reduce the negative impact of unauthorized entry.
impact of the illegal entry on these sites (Kuna, 2019). However, during the pandemic period, the vegetation coverage in these protected areas was also increased due to the curfew rule.

It is crucial to keep in mind that environmental disturbance may lead to more potential severe disasters and pandemics in the future. This brings up big question; “since environmental damages and future climate change may lead to more serious disasters, which will directly impact humanity, then, why are people not following the rules and regulations to protect their natural resources, which are important for human existence?”. A simple answer to this question is that people notice how dangerous the pandemic was in terms of the number of cases and death, as many people lost their lives and family members due to the pandemic. Consequently, the media, government sectors, and NGOs need to take effective actions on public awareness. Such attention to public awareness was never given to environmental issues, and climate change impacts, especially in developing countries. Therefore, improving governmental and public awareness of environmental and climate change impacts is one of the main challenges.

The governments took several actions during the COVID-19 period, which also differed between the countries. The major actions include the stay-at-home orders and the shutdown of most government sectors such as educational institutions, shopping malls, restaurants, gyms, commercial flights, etc. Some countries also implemented a full and partial curfew. For instance, Kuwait was under the full and partial curfew for six months, starting from February to August. Such roles, which were seriously enforced to the public and the intensive media awareness, played a significant role in limiting human activities, leading to better recovery of desert vegetation.

Such governmental actions reduced the major sources of disturbance, such as overgrazing and destructive camping, resulting in a higher recovery in native desert plants. These activities cause several detrimental impacts to desert ecosystems including degradation of biodiversity, spreading invasive species, soil erosion, and runoff (Kairis et al., 2015). During the pandemic period, the government restricted camping activities and minimized grazing activities by providing permissions for grazing once a week. Such restrictions supported the recovery of native desert vegetation. Therefore, there is an urgent need to adopt more serious management strategies to protect native desert plants, as well as the enforcement of environmental regulations. It is also necessary to provide civil communities with clear messages regarding

![Vegetation coverage at Wadi Al-Batin tristate desert using Sentinel-2 imageries during 2017–2020: (A) 2017, (B) 2018, (C) 2019, and (D) 2020.](image-url)
the impact of their activities on human well-being, including air quality, food security, and natural resources sustainability. The present study recommends that serious governmental actions need to be considered in when developing sustainable strategic planning, as well as enforcing the environmental rules and regulations to support the rapid autogenic recovery of native desert vegetation.

5. Conclusions

This study provides the power of using Sentinel images (10 m) based on NDVI analysis to assess the impact of lockdown during the COVID-19 on the native vegetation recovery of Wadi Al-Batin Tri-state Desert. It also provides a successful lesson on the resilience of desert ecosystems during the COVID-19 period. It could be concluded that COVID-19 indirectly produced some positive impact on the environment, as the lockdown in the arid lands led to restricting many activities, including quarrying, overgrazing, distractive camping, and off-road vehicle movements, reflecting on improvement of desert vegetation growth. The results indicated an increase in vegetation coverage during the pandemic in open and protected areas. These findings proved that the native desert vegetation rapidly recovered once the source of the disturbance was removed, and the environmental rules were enforced. This demonstrates that public communities can be a part of the solution.
when they analyze the long and short term impacts of anthropogenic activities on human wellbeing. The protection of native desert vegetation is the responsibility of public communities besides governments and all other relevant stakeholders. Thus, the intensive awareness of environmental impacts via media and the law enforcement are highly recommended, as well as promoting regional collaboration regarding the protection of natural resources and ecosystems.

Ethical statement

We declare that all ethical practices were followed in relation to the development, writing and publishing of the article.

CRediT authorship contribution statement

Zahraa M. Al-Ali: Conceptualization, Visualization, Methodology, Data Collection, Formal analysis, Writing – original draft. Meshal M. Abdullah: Conceptualization, Visualization, Methodology, Supervision, Writing – review & editing. Amjad A. Assi: Formal analysis, Visualization, Writing – review & editing. Mansour S. Alhumimidi: Data Collection, Writing – review & editing. Al-Qurnawi S. Wasan: Data Collection, Writing – review & editing. Thamer S. Ali: Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rse.2021.100557.

References

Abdullah, M.M., Al-Ali, Z.M., Abdullah, M.M., Srinivasan, S., Asiz, A.T., Al Atiqi, S., Al-Sulaimi, J.S., Pitty, A., 1995. Origin and depositional model of Wadi Al-Batin and its associated alluvial fan, Saudi Arabia and Kuwait. Sediment. Geol. 97, 203–229.

Al-Awadhi, J., Omar, S., Misak, R., 2005. Land degradation indicators in Kuwait. Land Degrad. Dev. 16, 163–176.

Alzahrani, M., Ahmad, M.N., Jones, P., Albar, H., Rahman, M.A., 2012. Recent climate change in the Arabian Peninsula: seasonal rainfall and temperature climatology of Saudi Arabia for 1979–2009. Atmos. Res. 111, 29–45.

Asaad, A.M., Al-Rewaily, S.L., El-Ilana, M.I., Abood, A.A., Dar, B.A., Hegazy, A.K., 2019. Impact of off-road vehicles on soil and vegetation in a desert rangeland in Saudi Arabia. Saudi J. Biol. Sci. 26, 1187–1193.

Baldaans, J.M., 2020. COVID-19 lockdown effects on air quality by NO2 in the cities of Barcelona and Madrid (Spain). Sci. Total Environ. 741, 140353.

Bannari, A., Al-Zubi, Z.M., 2020. Assessing climate change impact on soil salinity dynamics between 1987–2017 in arid landscape using Landsat TM, ETM+ and OLI data. Rem. Sens. 12, 2794.

Bannari, A., Morin, D., Bonna, F., Huete, A., 1995. A review of vegetation indices. Rem. Sens. Rev. 15, 95–120.

Berman, J.D., Ebi, K., 2020. Changes in US air pollution during the COVID-19 pandemic. Sci. Total Environ. 739, 139664.

Bhatnagar, S., Gill, L., Johnston, P., Waldren, S., Ghosh, B., 2020. Mapping vegetation communities inside wetlands using Sentinel-2 imagery in Ireland. Int. J. Appl. Earth Obs. Geoinf. 88, 102083.

Bujheji, M., De Costa Cunha, K., Beku, G., Mavric, B., De Souza, Y., De Costa Silva, S.S., Hanafi, M., Yein, T.C., 2020. The extent of covid-19 pandemic socio-economic impact on global poverty. a global integrative multidisciplinary review. Am. J. Econ. 10, 213–224.

Chen, K., Wang, M., Huang, C., Kinney, P.L., Anastas, P.T., 2020. Air pollution reduction and mortality benefit during the COVID-19 outbreak in China. The Lancet Planetary Health 4, e210–e212.

Corlett, R.T., Primack, R.B., Devictor, V., Maas, B., Gowsami, V.R., Bates, A.E., Koh, L.P., Regen, T.J., Loyola, R., Pakeman, R.J., 2020. Impacts of the coronavirus pandemic on biodiversity conservation. Biol. Conserv. 246, 108571.

Cucinotta, D., Vanelli, M., 2020. WHO declares COVID-19 a pandemic. Acta Biomed.: Atenei Parmense 91, 157.

Cui, X., Gibbes, C., Southworth, J., Waylen, P., 2013. Using remote sensing to quantify vegetation change and ecological resilience in a semi-arid system. Land 2, 108–130.

Drozd, M., Del Bello, U., Cartier, S., Colin, O., Fernandez, V., Gascon, F., Hoersch, B., Isola, C., Laberieti, P., Martinot, P., 2012. Sentinel-2: ESA’s optical high-resolution mission for GMES operational services. Rem. Sens. Environ. 120, 25–36.

El Zowalaty, M.E., Young, S.G., Jarbult, J.D., 2020. Environmental impact of the COVID-19 pandemic—a lesson for the future. Infect. Ecol. Epidemiol. 10.

Fadare, O.O., Okofo, E.D., 2020. Covid-19 face masks: a potential source of microplastic fibres in the environment. Sci. Total Environ. 737, 140279.

Foody, G.M., Palubinskas, G., Lucas, R.M., Curran, J.P., Honzak, M., 1996. Identifying terrestrial carbon sinks: classification of successional stages in regenerating tropical forest from Landsat TM data. Rem. Sens. Environ. 55, 205–216.

Haddel, A., Jabbar, M., Chen, X., 2009. Application of remote sensing and GIS to the study of land use/cover change and urbanization expansion in Basrah province, southern Iraq. Geo Spatial Inf. Sci. 12, 135–141.

Halmy, M.W.A., 2019. Assessing the impact of anthropogenic activities on the ecological quality of arid Mediterranean ecosystems (case study from the northwestern coast of Egypt). Ecol. Indicat. 101, 992–1003.

Harris, A., Carr, A., Dash, J., 2014. Remote sensing of vegetation cover dynamics and change across southern Africa. Int. J. Appl. Earth Obs. Geoinf. 28, 131–139.

Hassanein, H., Almazroui, M., 2015. Rainfall: features and variations over Saudi Arabia, a review. Climate 3, 578–626.

Huete, A., Didan, K., Miura, T., Rodriguez, E.P., Gao, X., Ferreira, L.G., 2002. Overview of the radiometric and biophysical performance of the MODIS vegetation indices. Rem. Sens. Environ. 83, 195–213.

Kairis, O., Karavitis, C., Salvati, L., Kounalaki, A., Kosmas, K., 2015. Exploring the impact of overgrazing on soil erosion and land degradation in a dry Mediterranean agroforest landscape (Greece)’s. Land Res. Manag. 29, 360–374.

Khalaf, F.I., Al-Awadhi, J., Misak, R.F., 2013. Land-use planning for controlling land degradation in Kuwait. Developments in Soil Classification, Land Use Planning and Sustainable Development Goals and COVID-19. Cambridge University Press, Cambridge.

Kuna, V., 2019. URL. https://www.kuna.net.kw/ArticleDetails.aspx?id=2771330&Language=ar-EN. (Accessed 28 October 2020).

Leal Filho, W., Brandli, L.L., Lange Salvia, A., Rayman-Bacchus, L., Platje, J., 2020. COVID-19 and the UN sustainable development goals: threat to solidarity or an opportunity? Sustainability 12, 5345.

Mandal, I., Pal, S., 2020. COVID-19 pandemic persuaded lockdown effects on environment over stone quarrying and crushing areas. Sci. Total Environ. 732, 119281.

Nakada, I.Y.K., Urban, R.C., 2020. COVID-19 Pandemic: Impacts on the Air Quality during the Partial Lockdown in Sao Paulo State. Science of the Total Environment, Brazil, p. 139087.

Nassrallah, H., Nieplova, E., Ramadani, E., 2004. Warm season extreme temperature events in Kuwait. J. Arid Environ. 56, 357–371.

Prata, J.C., Silva, A.L., Walker, T.R., Duarte, A.C., Rocha-Santos, T., 2020. COVID-19 pandemic repercussions on the use and management of plastics. Environ. Sci. Pollut. 54, 7760–7765.

Rouse, J., 1973. Monitoring the Vernal Advancement and Retradgation of Natural Vegetation [NASA/USGS Type II Report]. NASA/Goddard Space Flight Center, Greenbelt, MD.

Sachs, J., Schmidt-Truhl, G., Kroll, C., Lafortune, G., Fuller, G., Woon, F., 2020. The Sustainable Development Goals and COVID-19. Cambridge University Press, Cambridge.

Segarra, J., Buchaillot, M.L., Arna, J.L., Kefauver, S.C., 2020. Remote sensing for precision agriculture: sentinel-2 improved features and applications. Agroonomy 10, 192021.

Sharma, S., Zhang, M., Gao, J., Zhang, H., Kota, S.H., Lee, D.I., 2017. Characteristics of climate variation indices in Iraq using a statistical factor analysis. Int. J. Climatol. 37, 918–927.

Song, C., Woodcock, C.E., Seto, K.C., Lenney, M.P., Mackomer, S.A., 2001. Classification and change detection using Landsat TM data: when and how to correct atmospheric effects? Rem. Sens. Environ. 72, 230–243.

Van Fan, Y., Jiang, P., Hemzal, M., Klems, M., Kune, E., 2020. An impact of COVID-19 influence on waste management. Science of the Total Environment, p. 142014.

Veron, S.R., Blanco, J.J., Teixeira, M.A., Irurzun, J.G.N., Parruelo, J.M., 2018. Desertification and ecosystem services supply: the case of the Arid Chaco of South America. J. Arid Environ. 159, 66–74.

WHO, 2020. Coronavirus Disease (COVID-19) Situation Report. World Health Organization, p. 162. https://apps.who.int/iris/handle/10665/332970.
Xu, D., 2018. The impact of desertification dynamics on regional ecosystem services: a case study of Inner Mongolia (China). Community Global Ecology of Deserts 11.

Zambrano-Monserrate, M.A., Ruano, M.A., Sanchez-Alcalde, I., 2020. Indirect effects of COVID-19 on the environment. Science of the Total Environment, p. 138813.

Zhu, G., Tang, Z., Chen, L., Shangguan, Z., Deng, L., 2018. Overgrazing depresses soil carbon stock through changing plant diversity in temperate grassland of the Loess Plateau. Plant, Soil Environmental Monitoring Assessment 64, 1–6.