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RESEARCH TITLE

Using GIS and NDVI applications to evaluate Storm Daniel impacts on El-Gabal El-Akhdar Area-Libya: Wadi El-kof as example

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Abstract

Cyclones and flooding are massive impacts of climatic changes. In September 2023, Storm Daniel stroked El-Gabal El-Akhdar area, Libya, with windy strong and heavy rain storm (70 - 80 km/h.) and caused flash floods in several cities and valleys (Wadis). This led to catastrophic influences on different levels including soil and vegetation coverage erosion in the area. The research aims to detect the spatial change of vegetation in Wadi AlKuf before and after the storm through the analysis of space visuals using ArcGIS with applications of The Normalized Difference Vegetation Index (NDVI) technique, and other methods. The results revealed that the study area was strongly affected by the storm and because of the heavy soil erosion, a number of different plant species, which form the natural vegetation on the slopes and wadi channel and banks were gone with water run-off. These plants include the following maquis shrub-land like *Juniperus phoenicea, Pistacia lentiscus, Arbutus pavarii, Olea europaea, Myrtus communis, Quercus coccifera, Cupressus sempervirens* and others which classified on IUCN red list. According to the calculations of the vegetation index (NDVI) and the mapping that reveals the change in the area of vegetation, the vegetative loss was estimated to reach about 30.75 Km^2.

Key Words: Libya; Climatic changes; Storm Daniel; vegetation coverage; ArcGIS; NDVI.

INTRODUCTION

Libya is located in North Africa with coastal strip of 1700 km on the Mediterranean Sea. Climatically, it characterized by the Mediterranean climate with hot drought long period summer and warm short rainy winter. The most precipitations are occurred in EL-Gabal El-Akhdar area which lies in the north eastern part of the country with average of 650 ml/year. Because of its ecological and environmental significance, EL-Gabal El-Akhdar (The Green Mountains) was considered to be one of the most important topographical phenomena in Libya (Qaiser and El-Gadi, 1984), which also included desert, wadis and prairies.

Climatic changes are having a massive impact in many areas of the world, this includes increased temperatures, drought, deforestation, cyclones and flooding. In 2005, Kerry Emanuel proposed and released for the first time the term "Medicanes" which referred to an amalgamation of the words Mediterranean and hurricane that characterized by high speed wind and heavy rainfalls and such this medicanes is Storm Daniel. However, in Libya, a weather system like Storm Daniel was unprecedented. Thus, it affected and influenced everything stroked.

According to Libya's National Meteorological Centre (LNMC), the windy strong and heavy rain storm (70 - 80 km/h.) reached EL-Gabal El-Akhdar on 10th September. This led and causing catastrophic damage like communications interruption, the fall of electricity towers and trees, dams collapsed, and on the humanitarian side at least 4,333 people were killed. Torrential rains of between 150 - 240 mm caused flash floods in several cities, including Al-Bayda, which recorded a new rainfall record with the highest daily rainfall rate of 414.1 mm/24h (LNMC). This rate is equal that which precipitate in year.

In Libya, precipitation and water runoff are the important hydrologic component in the water resources like valleys (Wadis), especially in El-Gabal El_akhdar which reached more than 30 wadis with different long, area and water capacity among them (Wadi Al kuf as an example). They represent a vital habitat for plants differs from other adjacent habitats that affecting vegetation density. Libyan flora is consisting of around 2000 plant species and most of them (more than 50%) are occurring in El-Gabal Al-Akhdar area (Cyrenaica district) (Qaiser and A. El-Gadi 1984). During the past years, different studies were conducted to explore the Libyan flora and vegetation cover, especially of wadis (Ali & Jafri 1977; Asker 1998; El-Darier and El-Mogaspi, 2009; El-Barasi, et al., 2003; El shatshat et al., 2009; Alaib et al., 2017; Al-Traboulsil, and Alaib 2021).

Wadi Al kuf is covered with the most of 50% of Libyan flora (Ammar 2019). Slopes and banks of the wadi are covered with dense chaparral vegetation consisting of several species such as the following maquis tree like forms: *Juniperus phoenicea, Cedrus atlantica (cultivated), Pistacia lentiscus, Arbutus pavarii, Olea europaea, Myrtus communis, Quercus coccifera* and *Cupressus sempervirens*, (Qaiser and A. El-Gadi 1984).

Detection the spatial changes of vegetation using GIS and NDVI is taking place during last years. Many studies were used these technics and revealed the changes due to different factors like human activities, climatic changes, desertification and others that affecting the vegetative cover (Gandhi et al., 2015; Sadek et al., 2020; Hussein and Alnajim 2020).

Because of Storm Daniel, the Wadis (seasonal rivers) of the area were overflowed their banks by high level of water (for example, wadi Derna was 50 metres on each side). This caused heavy and strong water flow and run-off in wadi channels, and respectively, erosion of soil and plants. In this study, we tried to shade some light on the ecological impacts of Storm Daniel on Wadi alkuf vegetation and estimate the vegetative loos using the assessment of

vegetation by Geographic Information System (GIS) and Remote Sensing (RS), in addition, applications of The Normalized Difference Vegetation Index (NDVI) technique.

MATERIAL AND METHODS

Study area: Wadi Al Kouf area is a valley located in north eastern part of Libya and it is far around 18 Km north-west of Al-Bayda city. It lies between latitudes 32.5ºN and 32.8ºN and longitudes 21.4ºE and22.00ºE, and it starts gradually from the north coast to south with elevation of 0 m to 800 m above main sea level, with total area about 950 Km^2 (Figure 1). This wadi is characterizing with rocky low cliff formation on both side (banks) of the valley (ben Amer & Shakman, 2013).

Data analysis: the data before and after Storm Daniel were collected and divided in two parts; the first part was to evaluate and analyze data using ArcGIS with applications of The Normalized Difference Vegetation Index (NDVI) technique. It was used for extracting the various features presented in the Satellite images of Wadi Alkuf area. The second part is collecting data and using available information, literatures, references and different visits to the study area. The comparisons between the available data before and after the storm were used to estimate the vegetative loos.

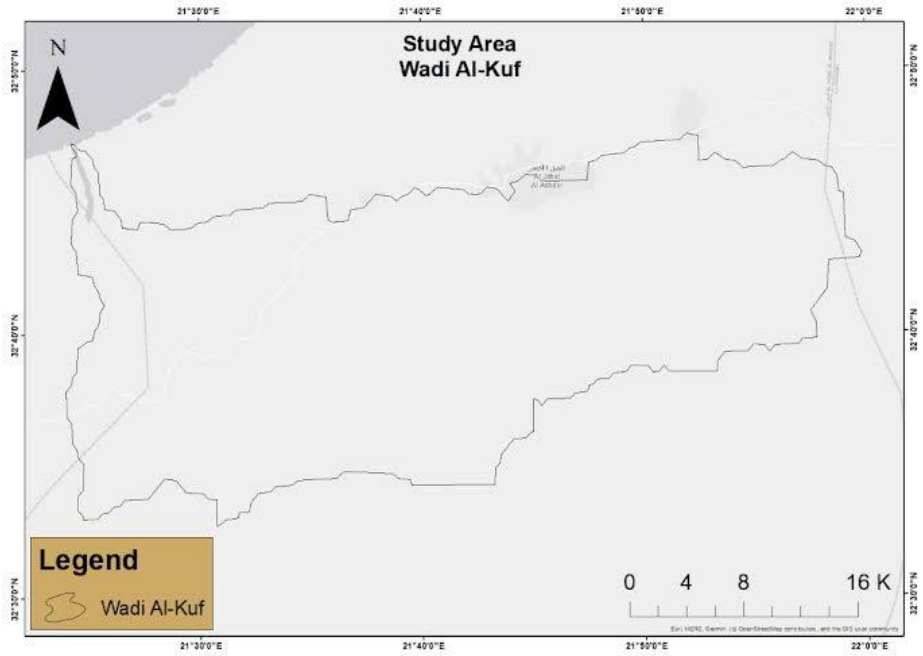

Figure 1, The location of study area Wadi Al-kuf

RESULTS ND DISCUSSION

As shown in figure 2, 3, and 4, the field visits to the study area revealed the devastation caused by the catastrophic flooding. Clearly the rainfall associated with Storm Daniel was extreme and there is no doubt that the magnitude of the damage indicates that a rainfall-induced river flood was formed. This large total might have exceeded the Wadi structure which naturally is not adapted to like this climatic changes and subsequently, avoid serious damage.

Water-induced soil erosion high values were observed in the study area that exposed to heavy rains (Figure 4). Despite the soil erosion varied from low to high erosion, but here, the effects of Storm on soil were very high while a Hugh number of tons of soils and sediments transport in highly variable spatially processes (Figure 4). Even though the vegetation coverage in the Wadi channels and on the side banks before the flooding was characterized as aged, rough and dense, but this could not prevent the erosion (Figure 2). The most likely scenario is, that

storm-flow behave as overwhelmed and releasing a torrent of water and sediment downstream.

Figure 2. The catastrophic effect of Storm Daniel on Wadi Al kuf area from different locations. Left up, the wadi with the old bridge which established during Italian occupation before the flooding, and down, the devastation caused by the catastrophic flooding. Note the absence of the bridge, roads and vegetation. Right up the wadi new bridge. Note the differences between before flooding "up" and after flooding " down". Photos were caputured by the Libyan photographer Ali Al saadi (Al saadi, A., personal communication, October 10, 2023).

Figure 3. The erosion and absence of vegetation from Wadi channel, banks and slopes of the mountain.

Figure 4. The soil erosion of the channel and banks of Wadi Al kuf. appearance of white rocks and eroded alluvial soil is clearly notable

The results of Satellite images and NDVI analysis showed that the vegetation of study area was affected by Storm Daniel. There was a clear change in the size, density, spread and distribution of vegetation cover in the area before and after the flood. The range of NDVI values ranged between (- 0.50) and (0.66) before the flood, while they were (- 0.37) and (0.535) after the flood (Figure 2). This reflected to what extent the storm influenced the area, especially in Wadi channels and banks which appeared as light color in the mettle of figure 5 after the storm.

According to USGS Remote sensing phenology, the NDVI values were classified to three classes; very low, moderate, and high NDVI (Table 1). From the results of NDVI calculations and analysis, it is clear that the vegetation coverage is consists of values of 0.66 and 0.535 which pointed to moderate and high dense vegetation like trees or sparse vegetation such as shrubs and grasslands. This reflect that the shrubs and trees was formed the most vegetative coverage in the study area. On the other, the low values (-0.5 and -0.37) were reflected areas with very low vegetation.

The study revealed that both high and low NDVI values were decreased after the flood with factor of (0.129) and (-0.130), respectively. The calculations of the vegetation index (NDVI) and the mapping indicated to the change in the area of vegetation and the vegetative loss was estimated to reach about 30.75 Km^2.

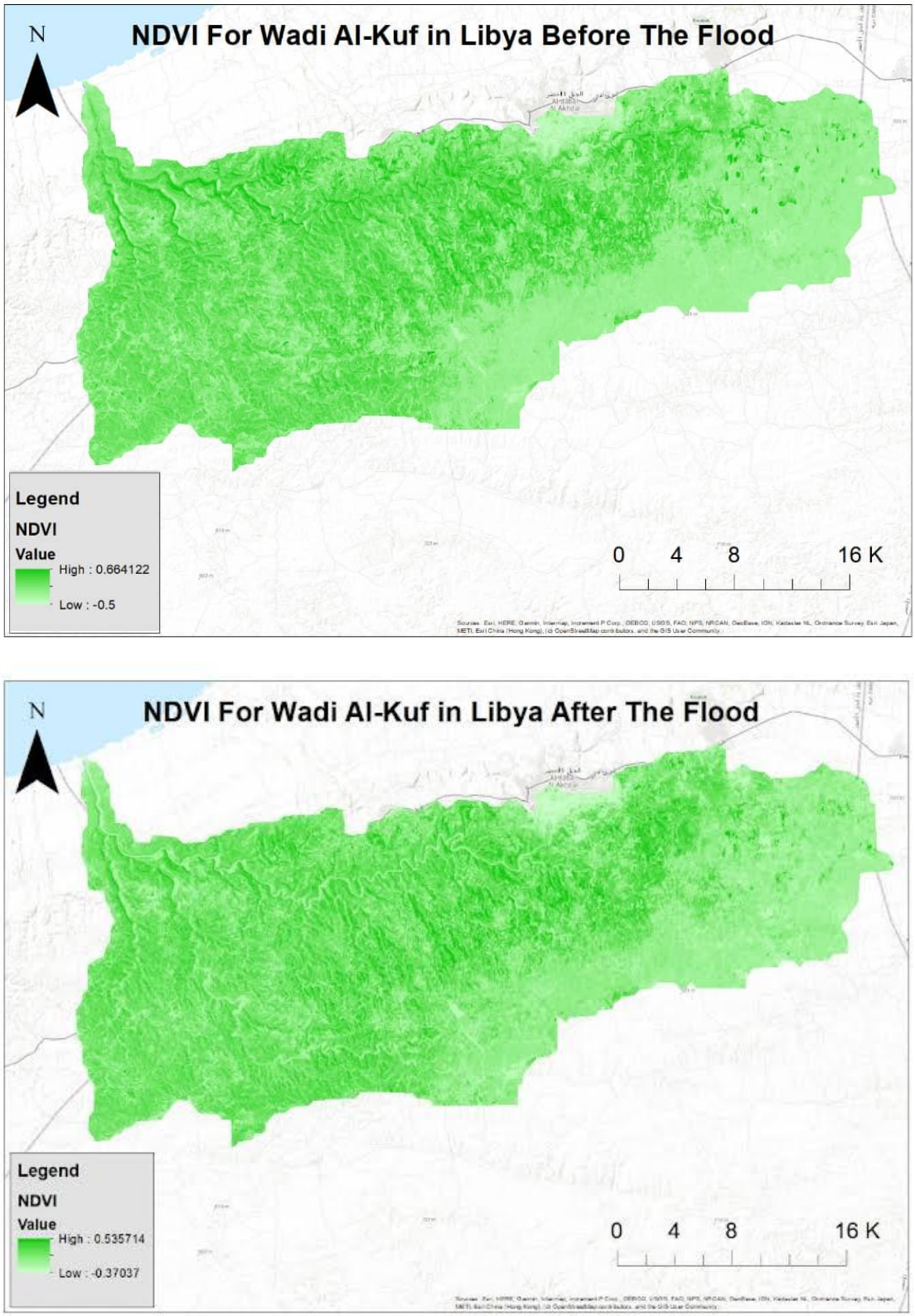

Figure 5. The effect comparison of pre-flood (top) and post-flood (bottom) on the vegetation of wadi Al-Kuf area.

Table 1. The classification of NDVI values according to USGS Remote sensing phenology.

NDVI Classes	NDVI Value
Very Low NDVI	≤0.1
Moderate NDVI	0.2 to 0.5
High NDVI	0.6 to 0.9

Floods are a significant environmental threat for plants (Pucciariello et al., 2014). Plants form the coverage or grow on the Wadi channel and the banks like *Juniperus phoenicea, Cedrus atlantica, Pistacia lentiscus, Arbutus pavarii, Olea europaea, Myrtus communis, Quercus coccifera* and *Cupressus sempervirens*, were also eroded through the water run-off. Due to rich vegetation of Al-Kuf valley (Wadi), and its floristic composition, a number of plants which mentioned as medicinal value (Al-Traboulsil and Alaib 2021), threatened or endemic plants (El-Darier and El-Mogaspi, 2009; AL rishi 2022) are most strongly influenced. Table 2 shows plant species including endemic and medicinal plants which thought to be affected by different degrees of devastation.

The location, topographic structures, environmental and climatic characteristics were offered a good growth conditions for a specific number of plant and animal species and, of course, these factors played a major role in richness and biodiversity of Wadi Al-Kuf compare to the rest of El-Gabal Al-Akhdar area especially adjacent valleys. Therefore, it had chosen in 1979 to be protected area for wild life with an area of 9000 hectares (Ben Amer & Shakman, 2013). According to the International Union for Conservation of Nature (IUCN, 2016; IUCN, 2021) and some local reports (El shatshat et al., 2009; El-Barasi & Saaed, 2013; Mosallam et al., 2017), different plant species were listed on the Red List or locally classified as critical with a different ranking. This include for example plants such as *Juniperous phonicea* L., *Arbutus pavarii* Pamp., *Cupressus sempervirens* L. var. *horizontalis* (Mill) Gord.

The findings of different studies, reported that the biological spectrum of Libyan flora consists of a number of life forms which described by Raunkeir, but the annuals and perennials are common and dominant (El shatshat and Mansour 2014; Alaib et al., 2016, Al-Traboulsi1 and Alaib 2021). This also clearly was found in Wadi Al-kuf and reflected the climatic conditions in the study area. The trees and shrubs (Perennials) can avoid the dry summer period by their sclerophyllous morphological or physiological characteristics, while the annuals to preserve their genetics, escape from unsuitable conditions as seeds in or on the soil forming the seed bank. Unfortunately, the most seed banks of the area were eroded by the flood and this might lead to an imminent danger of genetic erosion, especially for the endemic plants occurred in the area (Table 2), which form more than 50% of the total endemic species of Libya (Qaiser and El-Gadi, 1984), in addition, plant species with ethnobotanical values (Al-Traboulsi1 and Alaib 2021). At the present, the picture about amounts and species is not clear enough, therefore, further work for seed banks is highly recommended.

A number of studies reported the relationship between channels vegetation and their flow conditions in both humid and dry land channels (Stromberg et al. 2006; Sandercock et al. 2007; Reynolds and Shafroth 2017; Feizbahr et al. 2021 and Riis and Biggs 2003). Sandercock et al., (2007) showed that the vegetation of dryland channels differs from humid channels because the major woody plants are phreatophytes which characterized with very long taproots.

Table 2. Some plants form vegetation coverage of Wadi Al-kuf including the endemic, forage and medicinal plants which mentioned on IUCN red list like *Arbutus pavarii* and others.

Plant species	Family
Arum cyrenaicum Hruby.	Araceae
Anthemis cyrenaica Coss. var. cyrenaica	Asteraceae
Anthemis cyrenaica Coss. var radiata Pamp.	Asteraceae
Anthemis taubertii Durand & Barratte.	Asteraceae
Bellis sylvestrsis var.*cyrenaica* Beg.	Asteraceae
Onopordum cyrenaicum Maire&Weill	Asteraceae
Convolvulus maireanum Pamp.	Convolvulaceae
Arbutus pavarii Pamp.	Ericaceae
Medicogo cyrenaica Maire& Weill.	Fabaceae
Trifolium cyrenaicum Pamp.	Fabaceae
Ballota andreuzziana Pamp.	Lamiaceae
Nepeta cyrenaica Quezel&Zaffran	Lamiaceae
Plantago cyrenaica Durand & Barratte.	Plantaginaceae
Libyella cyrenaica (Durand & Barratte) Pamp.	Poaceae
Poa pentapolitana H. Scholz	Poaceae
Allium negrianum Maire&Weiller.	Alliaceae
Allium ruhmerianum Asch.	Alliaceae
Athamant della- cellae Asch.	Apiaceae
Ferula marmarica Aschers	Apiaceae
Anthemis taubertii Durand & Barratte.	Asteraceae
Cynara cyrenaica Maire & Weill	Asteraceae
Echinops cyrenaicus Durand & Barratte	Asteraceae
Onopordum cyrenaicum Maire&Weill	Asteraceae
Nonea viviani DC.	Boraginaceae
Onosoma cyrenaicum Durand & Barratte	Boraginaceae
Ranunculus cyclocarpus Pamp.	Ranunculaceae
Linaria laxiflora Desf.ssp.*calcarlongum* Qaiser	Scrophulariaceae
Teucrium apollinis Maire& Weiller	Lamiaceae
Teucrium barbeyanum Asch.	Lamiaceae
Teucrium davaeanum Coss.	Lamiaceae
Teucrium zanonii Pamp	Lamiaceae
Orobanche cyrenaica Beck.	Orobanchaceae
Cyclamen rohlfsianum Aschers	Primulaceae

Bendix (1999) showed that number of factors such as stream power, elevation and valley width are playing major role in the effect on vegetation in water channels. In arid and semi-arid zones, with only occasional flow of water, the vegetation grows within the channel and the floodplain (Hooke 2023). Vegetation along the water channels increases the roughness (Hooke 2023, and Gholami and Khalegi 2013) and reduces flow energy and velocity (Azab et al., 2021). The roughness of vegetation coverage in such this area has a great effect on flow resistance during flood, and resistance against the flow depends on the flow conditions and plants (Azab et al., 2021). Unfortunately, the vegetation composition in the wadi could not standing (Figure 3) because of high flow stream power of Storm Daniel, even though it had the morphological features of the resistance and patterns of species richness along wadi channel and banks (Tabacchi et al. 1996).

According to the location of the study area as a semi-arid zone, the water stream and flow was very low during last four decades. This caused reduction of flow magnitudes which mostly leading to channel narrowing. The uneven distribution of little rainfalls of El-Gabal El-Akhdar area, Libya, caused water scarcity and some plants faced drought stress and phenomenon of die-back was appeared on different plant species like *Juniperous phonicea* L. Therefore, a number of plant species were mentioned and classified on red list of IUCN.

Vegetation Cover is one of most important biophysical indicator to soil erosion, which can be estimated using vegetation indices derived from the Satellite images. Repetitive and seasonal flash floods, occur in different countries like those in Mediterranean and north Africa (Hallouz et al., 2018; Almasalmeh et al., 2022; Azab et al., 2021), entails the soil layer by erosion and carry spatially large quantities of water and soil sediments (Singh et al. 2020). Azab et al., (2021), found that more than 5500 ton of sediments of Wadi Naghamish (Egypt) reached the wadi outlet. And the highest values were found in the sloping areas. Despite the flood is un-repetitive, this finding can be noticed in Wadi Al-Kuf (Figure 3 and 4).

Plants form the greatest habitat for a number of other organisms like wildlife animals. They provide a place to live, shelter, safety and food. Areas dominated by dense vegetation include herbs, grass lands and trees, might offered the suitable ecosystem for their life's and this affects as well their reproductive success and behavior patterns. The animals that live in a particular area, are greatly affected by the intensity natural disturbances and human activity. Due to the flood in Wadi Al-Kuf, the situation of wildlife fauna has become very difficult and more critical, because a number of plants which serve as habitat were destroyed and of course, a number of animals were directly killed or eroded by the flood.

One of major problems of fauna studies in Libya is scarcity and lack of information about the abundance and distribution of wildlife animals especially in El-Gabal Al-Akhdar. Some attempts from local researchers were tried to shade some light on some wild animals and their locations, fortunately, this includes wadi Al-Kuf. Al-Awami (1997), Abrahim (2009), Abd Elhamid (2012), Muhammed et al., (2018) and Algadafi (2019) reported that some wild animals were faced threats. according to the Red List of IUCN, *Hyaena hyaena* is listed as near threatened while others were on different levels of assessment (Table 3). It is important to note that habitat destruction is major threats to wildlife and therefore, fully recover takes time.

Table 3. wild animals of EL-Gabal El-Akhdar area and their assessment according to IUCN. Data from different resources.

Species	Family	IUCN assessment
Canis anthus variegatus	Canidae	***LC***
Canis aureus	Canidae	***LC***
Hyaena hyaena	Hyaenidae	***LC***
Hemiechiusauritus	Erinaceidae	***LC***
Jacusis jacusis	Jaculidae	***LC***
Jaculus jaculus jaculus	Jaculidae	***LC***
Lepus capeasis barceus	Leporidae	***LC***
Lepus capenasis	Leporidae	***LC***
Spalax ehrenbergi	Spalacidae	***DD***
Hystrix cristata	Hystericidae	***LC***
Mus musculus	Muridae	***LC***
Atelerix algirus	Erinaceidae	***LC***

Lynx (Felis) caracal	Felidae	***NT***
Caracal caracal	Felidae	***NT***
Felis lybica	Felidae	***LC***
Genetta genetta	Viverridae	***LC***
Microtus guentheri	Cricetidae	***LC***
Lctonyx libycus	Mustelidae	***LC***
Vulpes vulpes	Canidae	***LC***
Lepus whitakeri	Leporidae	***LC***
Allactaga tetradactyla	Dipodidae	***DD***
Pachyuromys duprasi	Muridae	***LC***
Pipistrellus kuhli	Vespertilionidae	***LC***
Rattus norvegicus	Muridae	***LC***
Eliomys quercinus	Gliridae	***NT***
Herpestes ichneumon	Herpestidae	***LC***
Vulpes vulpes aegyptica	Canidae	***LC***

Wadi Al-Kuf suffered a lot from Storm Daniel which removed the soil layers, destroyed natural vegetation, infrastructures as well as influenced the wild life. Because the storm stroked all the area of El-Gabal Al-Akhdar, and caused the same effects, this picture can imagine on other valleys with the same or different significant danger level. Thus, special consideration is required for the whole area and particularly Wadi Al-Kof. More studies and research to determine the eroded soil quantity and specific plant species, seed banks loss, wild life, rebuilt the infrastructure and the channels plans must take in account. In addition, the vegetation coverage rehabilitation programs using indigenous native species that tolerate more other ones, like *Ceratonea silique* L. should carefully studied.

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