Vegetation Cover Assessment at Shaumari Wildlife Reserve Using Satellite Sensors Data

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Abstract

The assessment of rangeland cover and health is fundamental for effective planning and for supporting sustainability efforts in arid lands including Jordan. The objective of this study is to evaluate the vegetation cover density and distribution in the Shaumari Wildlife Reserve over the period between 1991 and 2022 using remote sensing techniques. The Shaumari Wildlife Reserve natural rangelands (total area, 22 km^2) are managed by the Royal Society for The Conservation of Nature. Landsat satellite sensor data from Thematic Mapper (TM, Landsat-TM5), Enhanced Thematic Mapper Plus (ETM+) and Operational Land Imager (OLI) were used to derive the normalized difference vegetation index (NDVI) across growing seasons (March -July) and over the study period (thirty-two years). The results show that bare soil (NDVI: 0.0 – 0.1) and scattered vegetation (NDVI: 0.1-0.2) are the mainland cover classes in the reserve. The NDVI-Landsat showed that 70% (15.3 km^2) to 94% (20.7 km^2) of the reserve is classified as bare soil across the growing seasons (March, July) and over the study period from 1991to 2022. In addition, in July-August (1991-2022), the percentage of reduction in vegetation cover area (compared to March) ranged from 1% (1994) to 20% (2004). In terms of vegetation distribution, most grasses and shrubs were located in the northwestern side of the reserve across years. However, scattered vegetation was noticed in the southern part of the reserve in March 1991, 2004, 2016 and 2022. Interestingly, a significant positive relationship (R^2 = 0.66, P< 0.01) was found between Landsat-NDVI values and annual precipitation (vegetation cover area = 0.0341 × precipitation + 0.0484). Therefore, the fluctuation in vegetation cover across the years was partially attributed to harsh climatic conditions, especially rainfall. In conclusion, considering the limited vegetation cover density and distribution in the reserve, a potential management and conservation practices should be carried out to sustain and enhance the cover density and distribution for the reserve which is home to the Arabian Oryx in Jordan.

Keywords: NDVI, Landsat, Rangelands, remote sensing, drylands.

Introduction

Evaluating the distribution, quality, and density of rangelands is crucial for a well-informed planning and for the advancement of sustainability initiatives in arid regions (Sawalhah *et al.,* 2021). The appraisal of rangeland health encompasses the examination of soil and site stability, hydrologic functionality, and the overall integrity of the biotic community (Pyke *et al.* 2002; Tahat *et al*., 2020). Covering approximately 80% of Jordan's total land area according to MoEnv (2015), rangelands exhibit features typical of arid and semi-arid climates. In addition, the high grazing pressure decreases primary production, reduces biomass, and perennial grass in these degraded lands. In fact, Jordanian rangelands have been exposed to potential land degradation and biodiversity loss (Al-Karadsheh *et al.,* 2012).

Intense grazing pressure leads to a decline in primary production, a decrease in biomass, and a reduction in the basal cover of perennial grasses (Ash *et al*., 2011). As a result, the

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sustained grazing capacity of the land is diminished over the long term (Ash *et al.,* 2011). Furthermore, low precipitation and high temperatures in these harsh environments play a key role in vegetation distribution (Sawalhah *et al.,* 2021). Therefore, advanced and long-term management systems must be carried out in those dry rangelands to enhance the vegetation cover density, quality, and distribution. Tracking fluctuations in grazing intensity from year to year using conventional methods is a time-consuming and labour-intensive task, often hindered by the absence of suitable equipment (Dara *et al.,* 2020; Tadros *et al.,* 2020). Remote sensing methods offer a promising avenue for identifying rangelands where alterations in surface properties can be detected and linked to land degradation (Sawalhah *et al.*, 2018, 2021). For example, utilizing remotely captured data from the Landsat archives spanning from 1985 to 2017 in conjunction with ground reference information unveiled previously undiscovered areas of intense grazing activity during the Soviet era (Dara *et al*., 2020). Landsat datasets and Google Earth Engine were also employed by Xie *et al.* (2019) who developed a novel approach to mapping changes in vegetation cover density at the pixel level (spatial resolution: 30 m) and identified degraded lands with an overall classification accuracy of 82.6%. In Jordan, satellite images from Landsat effectively evaluated changes in land use and cover with a general precision ranging between 80% to 86% (Tadros *et al.,* 2020). Additionally, this approach demonstrated its capability to suggest the surveillance of invasive plant species such as *Prosopi*s spp. within the designated area (Tadros *et al.,* 2020). Overall, Landsat 8 Operational Land Imager (OLI) serves as a practical approach for detecting shifts in vegetation coverage density and measuring degradation within the Middle and Eastern rangelands (Badia) of Jordan (Sawalhah *et al*., 2018). Employing a change detection method with remotely-sensed data allows for the assessment of human impacts on a given area without introducing additional disruptions to ecologically delicate regions (Willis, 2015). In fact, the utilization of a remote sensing change detection strategy can strengthen the preservation of natural resources and ecological surveillance by tracking the diverse and ongoing ecological dynamics of the observed area, whether they are irregular, uniform, or continuous (Sergeant *et al*., 2012; Willis, 2015). Several remotely-sensed indices have been used to detect changes in vegetation cover density (Foran and Pearce, 1990; Othman *et al*., 2014, 2015; Tadros *et al.,* 2020). Perry and Lautenschlager (1984) found that twenty vegetation indices derived from surface reflectance data are functionally equivalent. However, the widely used method for estimating vegetation cover density by assessing chlorophyll content through remotely sensed data is represented by the normalized difference vegetation index (NDVI). This index was used in regional and continental-scale for vegetation monitoring (Foran and Pearce, 1990; Myneni *et al.,* 1997; Wang *et al*., 2004). The Royal Society for the Conservation of Nature (RSCN) established the Shaumari Wildlife Reserve as a wildlife reserve in Jordan in 1975. This reserve serves as a breeding ground and sanctuary for endangered species in Jordan, such as *Oryx leucoryx* in addition to conserving several native wild plant species (Abu Yahya *et al*., 2022; Amr *et al*., 2011). However, long-term changes in vegetation cover area (density and distribution) are not well understood. The missing information is critical for future monitoring and conservation plans. The objective of this study is to evaluate vegetation cover extent and density at the Shaumari Wildlife Reserve over the period from 1991 to 2022 using a remote sensing technique.

Materials and Methods

Site Description

The study was conducted at the Shaumari Wildlife Reserve (Figure 1) between 1991 and 2022. The Royal Society for the Conservation of Nature (RSCN) established

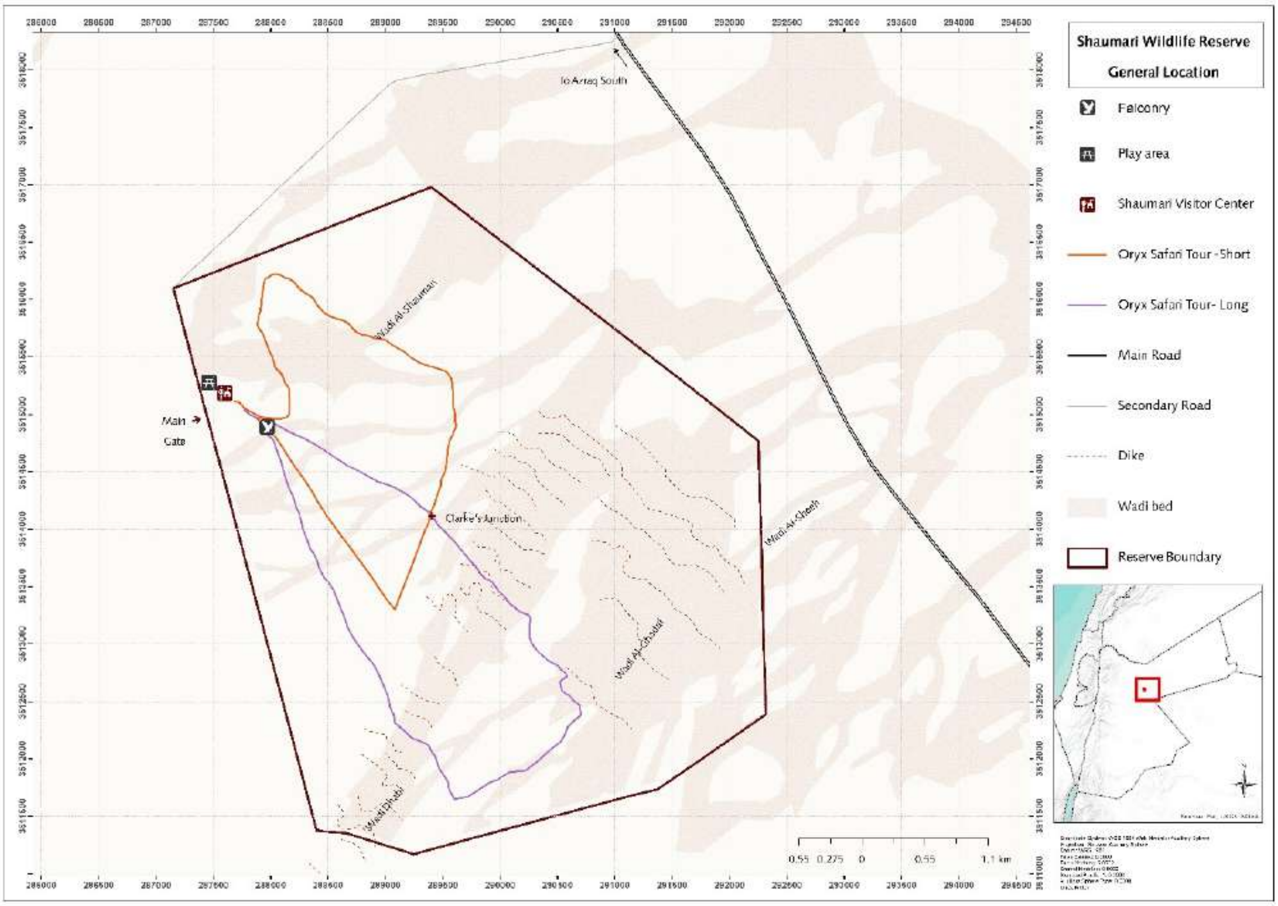

Figure 1. Shaumari Wildlife Reserve, Eastern Badia, Jordan.

the Shaumari Wildlife Reserve as a wildlife reserve in Jordan in 1975. The total area of the reserve is 22 km^2 with 60% of its total area consisting of wadis, while the remaining area is flat land covered in basalt stone (Hamad). The elevation ranges from 510 to 680 m. The reserve is situated in the desert biogeographical zone, which experiences varying temperatures. Summers can be very hot, with temperatures reaching up to 40°C, while cold days in winter can reach -10°C. The total rainfall in the area is very low, averaging less than 50 ml annually. The primary reason for the establishment of this reserve was to serve as a breeding ground and sanctuary for endangered species in Jordan, such as *Oryx leucoryx* (Figure 2), and to conserve wild plant species such as , *Retama raetam, Salsola vermiculata, Artemisia herba-alba, Achillea fragrantissima*, *Astragalus* spp., *Stipa* spp., *Trigonella* spp (Abu Yahya *et al.,* 2022; Amr *et al.*, 2011). Soil is very poor and mostly is hammada, saline, sandy-loam. Land degradation, which can be defined as the extreme reduction of biological diversity, is a significant issue in the area.

Image Acquisition and Processing

Cloud-free Landsat sensor images were downloaded from the earth-explorer portal (http://earthexplorer.usgs.gov/). The Landsat satellite sensor data used were Thematic Mapper (TM, Landsat-TM5), Enhanced Thematic Mapper Plus (ETM+) and Operational Land Imager (OLI). The downloaded images (Landsat-TM5, ETM+, OLI, collection-2 level-2) are classified as a Surface Reflectance Climate Data Records (CDRs) datasets, which are a reliable Landsat source for land cover studies (Qarallah *et al*., 2023). These datasets are atmospherically corrected using the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) program (Qarallah *et al.,* 2021, 2023). Images were geo-rectified using Environment for Visualizing Images (ENVI) 5.0 (Research Systems, Boulder, Colorado, USA).

Figure 2. Arabian Oryx (*Oryx leucoryx*) at the Shaumari Wildlife Reserve, Eastern Badia, Jordan.

Then, NDVI (Eq. 1) was derived and assigned to different classes (Table 1) (Abu Yahya *et al*., 2022; Atun *et al*., 2020).

$$NDVI = \frac{(Near\ infrared\ band\text{-}red\ band)}{(Near\ infrared\ band+red\ band)} \quad \text{(Eq. 1)}$$

During the study period, two images per year were selected. The two images (during each year) where when vegetation cover density had the highest (February-March) and lowest (July-August) NDVI values. This step facilitated the comparison process between reserves and determined the maximum and minimum vegetation cover density across the year. In addition, the NDVI classes which represented spares vegetation to dense (0.1-0.6) were summed together and correlated to rainfall data (Figure 3) in order to understand the impact of climatic condition on the reserve vegetation cover density. SigmaPlot software 14.0 was used to graph the data and derive the regression model.

Results

The vegetation cover density and total area for the Shaumari Wildlife Reserve in March (1991 to 2022) are presented in Table 2. Remotely-sensed data revealed that most of the reserve area consisted of bare soil.

The NDVI values in March ranged from < 0.1 (bare soil) to 0.4 (dense vegetation). The NDVI-Landsat showed that the total area, which is classified as bare soil in March, ranged from 15.3 to 20.7 (reserve total area, 22 km^2) over the period from 1991 to 2022 (Table 2). In addition, the maximum vegetation cover density was recorded during the years 1991, 2004 and 2016.

Figure 4 presents the vegetation cover density and distribution in March over the period between 1991 and 2002. Satellite images show that the vegetation density was consistently concentrated in the Northwest side of the reserve over the years (Figure 3). In addition, scattered vegetation was noticed in the southern part of the reserve. In March 1991, 2004, 2016 and 2022.

In July-August 1991-2022, NDVI data which were derived using Landsat-5 (TM), Landsat-7 (ETM+) and Landsat 8 (OLI) showed that the vegetation values in July ranged from < 0.1 (bare soil) to 0.3 (moderate vegetation) (Table 3, Figure 5). In addition, the vegetation coverpercentage in July was lower than that in March (Table 3). The percentage of reduction in the vegetation cover area in July (compared to March) ranged from 1% (1994) to 20% (2004). However, the total reduction in vegetation in

Table 1. Normalized difference vegetation index (NDVI) classes.

Class	Features
Negative values	Deep and shallow water.
0.0 - 0.1	Barren areas of rock and sand.
0.1 - 0.2	Scattered vegetation.
0.2 - 0.3	Moderate shrubs and grasslands.
0.4 - 0.6	Agricultural area, agroforestry, intense vegetation cover density.
0.6 – 0.9	Dense forests.

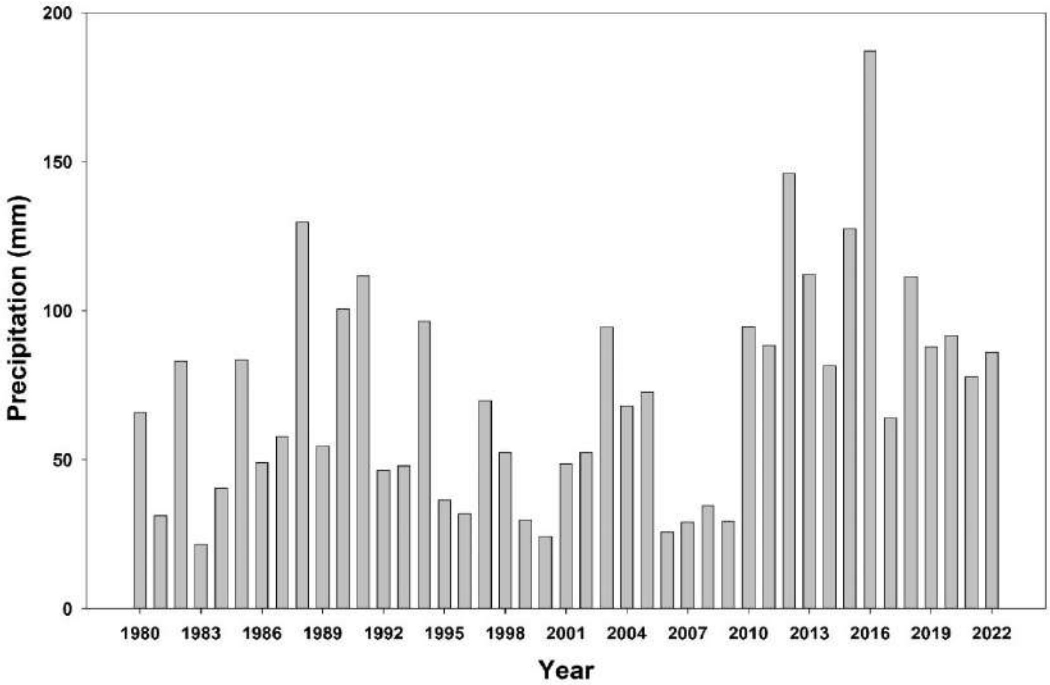

Figure 3. Long-term annual precipitation (1980-2022) for the Shaumari Wildlife Reserve, Eastern Badia, Jordan.

Table 2. Normalized Difference Vegetation Index (NDVI) classes for the Shaumari Wildlife Reserve (total area, 22 km^2) in March 1991-2022. NDVI class's data was derived using Landsat-5 (TM), Landsat-7 (ETM+) and Landsat 8 (OLI) sensors data.

	NDVI classes (area km^2)			
Year	**0.0 - 0.1**	**0.1 - 0.2**	**0.2 - 0.3**	**0.3 - 0.4**
1991	17.4	4.19	0.4	0.006
1994	20.6	1.4	0	0
1999	20.7	1.3	0.003	0
2004	16.7	4.77	0.5	0.027
2006	20.3	1.67	0.03	0
2011	19.6	2.32	0.08	0
2016	15.3	6.63	0.07	0.0008
2021	20.4	1.55	0.05	0
2022	19.7	2.28	0.012	0

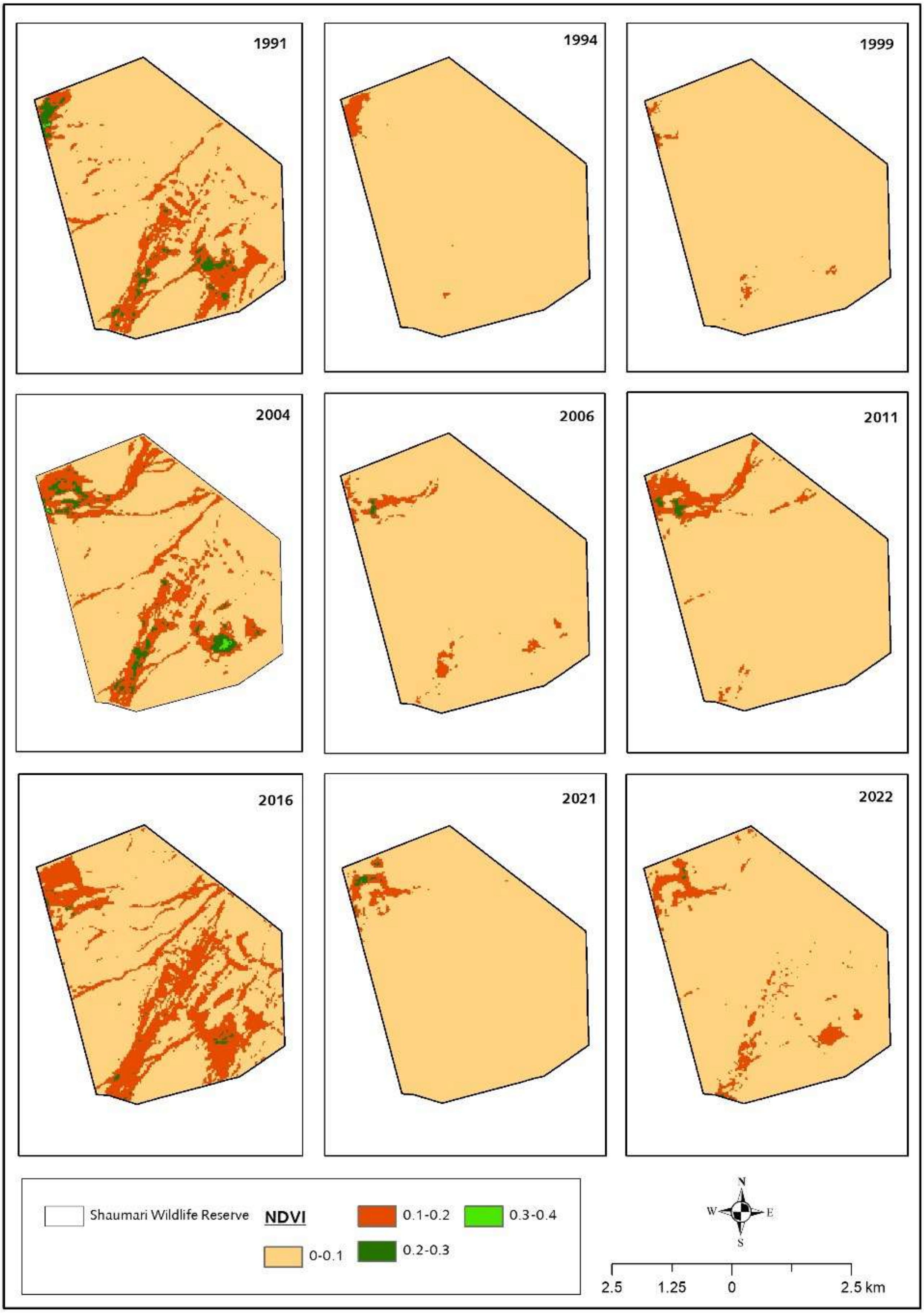

Figure 4. Vegetation cover density and distribution for the Shaumari Wildlife Reserve (total area, 22 km2) in March 1991-2022. NDVI class's data was derived using Landsat-5 (TM), Landsat-7 (ETM+) and Landsat 8 (OLI) sensors data.

July 2022 compared to March 2022 was about 5% (19.7 km^2 vs. 20.7 km^2). The vegetation distribution in July (Figure 5) was similar to that in March (Figure 4). Except in July 1991 and 2016, the vegetation was found in the Northwestern side of the reserve.

The simple linear regression model was used to estimate the relationship between the vegetation cover area, which was derived using normalized difference vegetation index (NDVI), and between precipitation during the study period 1991-2022 revealing a significant (P-value < 0.01) relationship (Figure 6). The coefficient of determination was 66%.

Table 3. Normalized Difference Vegetation Index (NDVI) classes for the Shaumari Wildlife Reserve (total area, 22 km^2) in July-August 1991-2022. NDVI class's data was derived using Landsat-5 (TM), Landsat-7 (ETM+) and Landsat 8 (OLI) sensors data.

	NDVI classes (area km^2)			
Year	**0.0 - 0.1**	**0.1 - 0.2**	**0.2 - 0.3**	**0.3 - 0.4**
1991	19.6	2.40	0	0
1994	20.7	1.30	0	0
1999	20.79	1.21	0	0
2004	20.75	1.25	0	0
2006	20.4	1.60	0	0
2011	20.4	1.60	0	0
2016	17.9	4.10	0	0
2021	20.8	1.19	0.0005	0
2022	20.7	1.29	0.003	0

Discussion

Rangelands, which account for almost a third of the Earth's ice-free land, stand as the most extensive land cover globally (Ellis and Ramankutty, 2008). However, they only contribute to approximately 11% of terrestrial net primary production (Ellis and Ramankutty, 2008). This is because rangeland are found primarily in arid and other low productivity areas with a high percentage of bare earth cover (Ellis and Ramankutty, 2008). In Jordan, rangelands constitute about 80% of Jordan's total land area (MoEnv, 2015) and are characterized by arid and semi-arid climates. While the nomadic pastoral lifestyle of Bedouins depends on animals and includes various practices, rangelands in Jordan face the risk of potential land degradation and a decline in biodiversity (Al-Karadsheh *et al*., 2012; Juneidi and Abu-Zanat, 1993).

Assessing the conditions of remote rangelands in Jordan presents significant logistical obstacles due to the requirement for frequent evaluations of ecological conditions across time and space (Sawalhah *et al*., 2018). Remote sensing was successfully used for land cover/land use assessment (Al-Kofahi *et al*., 2019; Othman *et al*., 2021; Tadros et al., 2020). In this study, NDVI was used to estimate the vegetation cover density in the Shaumari Wildlife Reserve which is managed by RSCN. Landsat-NDVI data for the reserve revealed potential changes in vegetation cover density over the years from 1991 to 2022. In each year, the NDVI values were between 0.1 and 0.4 in March, and ranged from 0.0 to 0.3 in July. Higher vegetation cover density in March (compared to July) can be attributed partially to the amount of soil moisture. During spring period (March-April), grasses were available and covered parts of the reserve. In summer (July-August), those grasses entered the senescence stage and die.

Patterns of change over time demonstrate that both land-use and rainfall variability

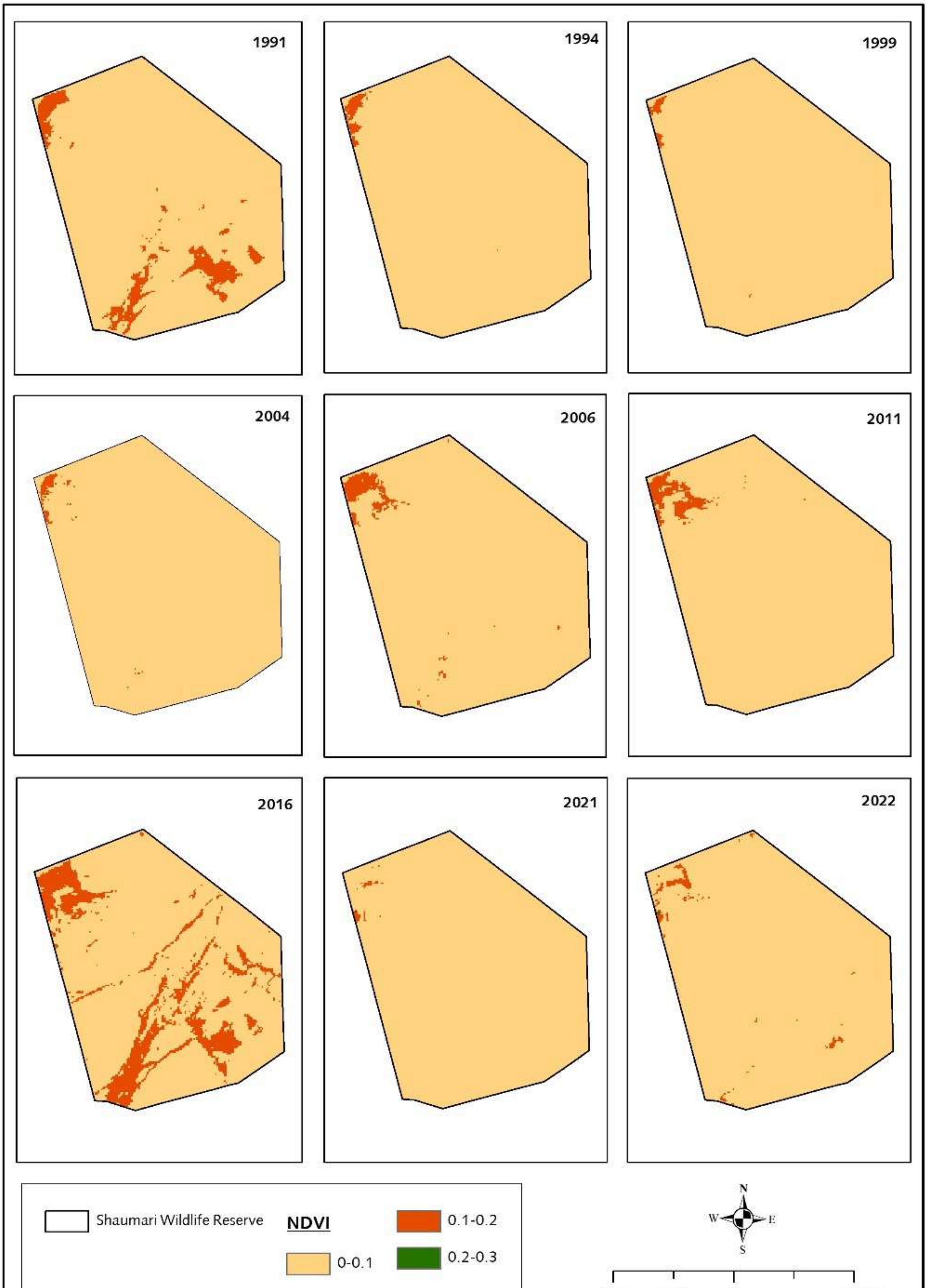

Figure 5. Vegetation cover density and distribution for the Shaumari Wildlife Reserve (total area, 22 km^2) in July 1991-2022. NDVI class's data were derived using Landsat-5 (TM), Landsat-7 (ETM+) and Landsat 8 (OLI) sensors data.

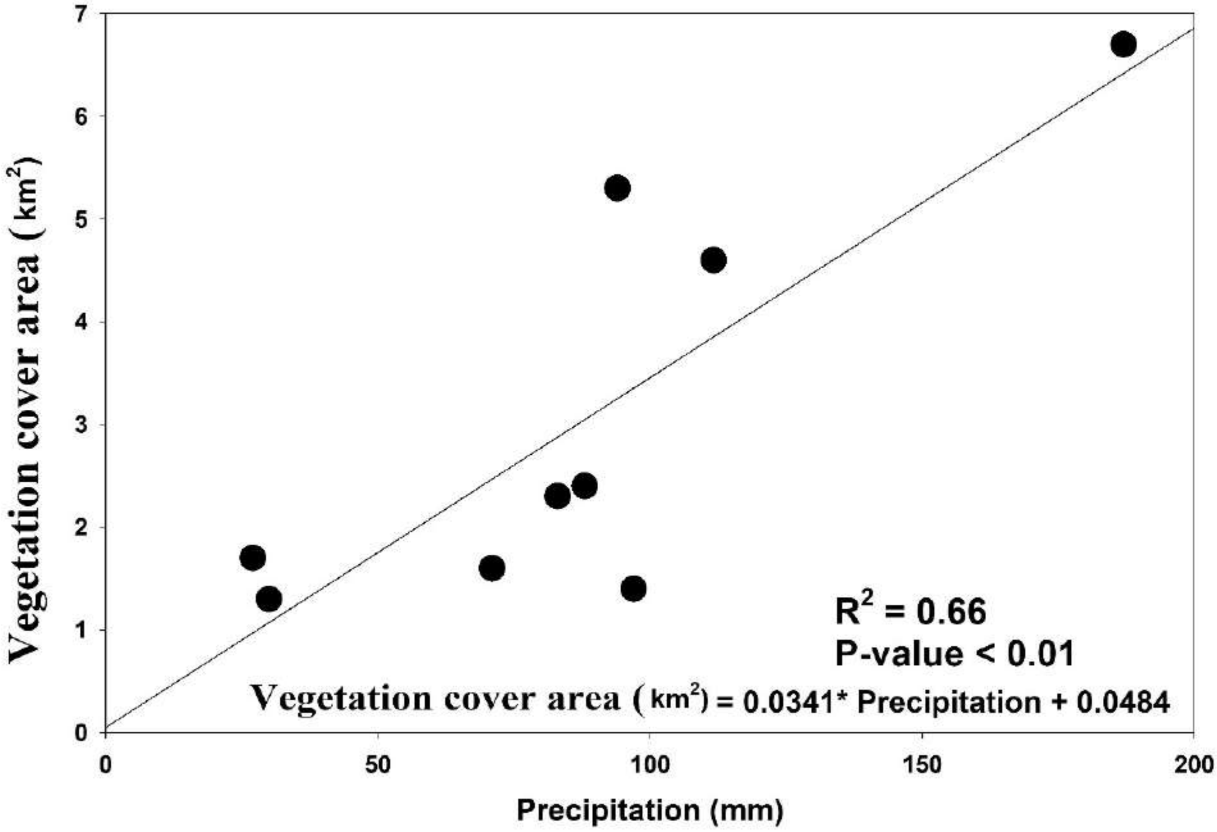

Figure 6. The relationship between the vegetation cover total area (dense + scattered),derived using normalized difference vegetation index (NDVI), and between precipitation during the study period 1991-2022.

influence vegetation cover density (Dube and Pickup, 2001). Given the varying effects of rainfall patterns and land utilization, it is important to consider whether intensified land use might hold comparable or even greater significance than climate change itself (Dube and Pickup, 2001). The application of high grazing intensity has the potential to elevate the vulnerability of both rangeland ecosystems and local populations to drought circumstances (Hein, 2006). Furthermore, during arid years, areas experiencing intensive grazing pressure witness substantial reductions in both above-ground biomass production and rain-use efficiency (Hein, 2006). In this study, the linear regression analysis of remote sensing and rainfall data revealed a moderate association (66%). Therefore, the fluctuation in the density and distribution of vegetation cover across years can be attributed to the harsh climatic conditions, especially rainfall. In Kuwait's rangelands, the plant cover was 83% and 70% less, and herbage production was 76% and 91% less in grazing areas (Zaman, 1997). In the same study, an average seasonal precipitation of 90 mm supported a mean of 223 kg ha^{-1} biomass, whereas an average mean seasonal precipitation of 73 mm maintained a mean phytomass of 102 kg ha^{-1} (Zaman, 1997). The process of vegetation change detection using satellite sensor data can determine pixel variations at different times to identify areas undergoing rapid changes (Willis, 2015). However, for accurate information from moderate resolution satellites (e.g. Landsat) ground surveys are essential for an accurate assessment of the remotely-sensed data (Qarallah et al., 2023; Abu Yahya *et al.*, 2022). Sawalhah *et al.* (2018) found that the overall accuracy of remote sensing data derived from Landsat to assess the density and distribution of the rangeland vegetation cover in Jordan in 2016 was 75%. Overall, utilizing open- access (free of charge) extensive sequences of remotely sensed data, notably Landsat (with over 40 years of free images), in combination with ground-referenced data, is considered as a feasible strategy for quantifying vegetation cover density (Tongway and Hindley, 2004).

Conclusions

Remote sensing techniques hold promises for detecting vegetation cover density and distribution. This advanced sensing approach reduced time, cost, and provided essential historical data records for the released sites (vegetation cover density for the 34 years). Landsat-NDVI images revealed that the northwestern side of the reserve had consistently the highest vegetation cover density over the growing season (March and July) andduringthe study period from 1991to 2022. A moderate and significant relationship was found between vegetation cover density and rainfall during the growing season. However, for precise information, further studies are recommended, especially ground survey assessments.

References

Abu Yahya, A, Othman, Y, Sawalhah, M and Holechek, J. 2022. The potential of remotely-sensed data to identify suitable sites for the reintroduction of Arabian Oryx (*Oryx leucoryx*). *Zoology in the Middle East,* **68(2):** 109–120.

Al-Karadsheh, E, Akroush, S and Mazahreh, S. 2012. Land Degradation in Jordan – Review of knowledge resources. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria.

Al-Kofahi, S, Gharaibeh, A, Bsoul, E, Othman, Y and Hilaire, R.2019. Investigating domestic gardens' densities, spatial distribution and types among city districts. *Urban Ecosystems*, **22**: 567–581.

Amr, Z, Modry, D and Shudiefat, M. 2011. **BADIA: The Living Desert**, 224. Amman, Jordan: Al Rai Printing Press.

Ash, A, Corfield, J, McIvor, J and Ksiksi, T. 2011. Grazing management in tropical savannas: utilization and rest Strategies to manipulate rangeland condition. *Rangeland Ecology and Management,* **64**: 223–239.

Atun, R, Kalkan, K and Gürsoy, Ö. 2020. Determining the forest fire risk with Sentinel 2 images. *Turkish Journal of Geosciences,* **1(1)**:21-25.

Dara, A, Baumann, M, Freitag, M, Hölzel, N, Hostert, P, Kamp, J, Müller, D, Prishchepov, A and Kuemmerle, T. (2020). Annual Landsat time series reveal post-Soviet changes in grazing pressure. *Remote Sens Environ,* **239:**111667.

Dube,O and Pickup,G .2001. Effects of rainfall variability and communal and semi-commercial grazing on land cover in southern African rangelands. *Climate Research*, **17(2):**195-208.

Ellis, E and Ramankutty, N.2008. Putting people in the map: anthropogenic biomes of the world. *Frontiers in Ecology and the Environment*, **6**:439-447.

Foran, B and Pearce, G.1990. The use of NOAA AVHRR and the green vegetation index to assess the 1988/1989 summer growing season in central Australia. In: Proceedings of 5th Australasian Remote Sensing Conference. Perth. Committee of the 5th Remote Sensing Conference: Perth. 198-207.

Hein, L. 2006. The impacts of grazing and rainfall variability on the dynamics of a Sahelian rangeland. *Journal of Arid Environments*, ***64*****(3):**488-504.

Juneidi, J and Abu-Zanat M.1993. Jordan Agricultural Sector Review: Low Rainfall Zone. Agricultural Policy Analysis Project, Phase II (APAP II), USAID, Amman, Jordan.

MoEnv (Ministry of Environment). 2015. The National Biodiversity Strategy and Action Plan (NBSAP). Amman-Jordan.

Myneni, R, Keeling, C, Tanser, C, Asrar, G and Nemani, R.1997. Increased plant growth in the northern high latitudes from 1981 to 1991. *Nature,* **386**: 698-702.

Othman, Y and Hilaire, R. 2021. Using

multispectral data from Landsat ETM+ to estimate leaf area index of pecan orchards. *Fresenius Environmental Bulletin* **30:** 2613-2618.

Othman, Y, Steele, C, VanLeeuwen, D, Heerema, R, Bawazir, S and Hilaire, R. 2014. Remote sensing used to detect moisture status of pecan orchards grown in a desert environment. *International Journal of Remote Sensing*, **35(3):** 949-966.

Othman, Y, Steele, C, VanLeeuwen, D and Hilaire, R. 2015. Hyperspectral surface reflectance data used to detect moisture status of pecan orchards during flood irrigation. *Journal of the American Society for Horticultural Science*, **140 (5):** 449-458.

Perry, C and Lautenschlager, L. 1984. Functional Equivalence of Spectral Vegetation Indices, *Remote Sensing of Environment*, **14**, 169-182.

Pyke, D, Herrick, J, Shaver, P and Pellant, M. 2002. Rangeland health attributes and indicators for qualitative assessment. *Journal of Range Management,* **55**:584-597.

Qarallah, B, Al-Ajlouni, M, Al-Awasi, A, Alkarmy, M, Al-Qudah, E, Bani Naser, A, Al-Assaf, A, Gevaert, C, Al Asmar, Y, Belgiu, M and Othman, Y. 2021. Evaluating post-fire recovery of Latroon dry forest using Landsat ETM+, unmanned aerial vehicle and field survey data. *Journal of Arid Environments,* **193**: 104587.

Qarallah, B, Othman, Y, Al-Ajlouni, M, Alheyari, H and Qoqazeh, B. 2023. Assessment of Small-Extent Forest Fires in Semi-Arid Environment in Jordan Using Sentinel-2 and Landsat Sensors Data. *Forests,* **14(1):**41.

Sawalhah, M, Al-Kofahi, S, Othman, Y and Cibils, A. 2018. Assessing rangeland cover conversion in Jordan after the Arab spring using a remote sensing approach. *Journal of Arid Environments,* **157**: 97-102.

Sawalhah, M, Othman, Y, Abu Yahya, A, Al-Kofahi, S, Al-Lataifeh, F, and Cibils, A. 2021. Evaluating the influence of COVID-19 pandemic lockdown on Jordan Badia rangelands. *Arid Land Research and Management,* **35**: 483-495.

Sergeant, C, Moynahan, B and Johnson, W. 2012. Practical advice for implementing long-term ecosystem monitoring. *Journal of Applied Ecology*, **49 (5):** 969–973.

Tadros, M, Al-Assaf, A, Othman, Y, Makhamreh, Z and Taifour, H. 2020. Evaluating the effect of *Prosopis juliflora*, an alien invasive species, on land cover change using remote sensing approach. *Sustainability,* **12**: 5887.

Tahat, M, Alananbeh, K, Othman, Y and Leskovar, D. 2020. Soil health and sustainable agriculture. *Sustainability,* **12**:4859.

Tongway, D and Hindley, N. 2004. Landscape function analysis: procedures for monitoring and assessing landscapes with special reference to mine sites and rangelands. *CSIRO Sustainable Ecosystems,* Brisbane, Australia.

Wang, J, Rich, P, Price, K and Kettle, W. 2004. Relationships between NDVI and tree productivity in the central great plains. *International Journal of Remote Sensing*, **25**: 3127-3138.

Willis, K. 2015. Remote sensing change detection for ecological monitoring in United States protected areas. *Biological Conservation*, **182**: 233-242.

Xie, Z, Phinn, S, Game, E, Pannell, D, Hobbs, R, Briggs, P and McDonald-Madden, E. 2019. Using Landsat observations (1988–2017) and google earth engine to detect vegetation cover changes in rangelands – A first step towards identifying degraded lands for conservation. *Remote Sensing of Environment*, **232**: 111317.

Zaman, S.1997. Effects of rainfall and grazing on vegetation yield and cover of two arid rangelands in Kuwait. *Environmental Conservation*, **24(4):**344-50.