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تقييم التأثير الجيومورفولوجي غير المباشر للإنسان في كثافة نبات الثندى الناتج من التخييم في صحراء دولة الكويت

فيصل عنزة

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تقييم التأثير الجيومورفولوجي غير المباشر للإنسان في كثافة نبات الثندى الناتج من التخييم في صحراء دولة الكويت

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ملخص

هدف الدراسة: تهدف هذه الدراسة إلى تقييم التأثير الجيومورفولوجي غير المباشر للإنسان الناتج من التخييم في صحراء دولة الكويت على كثافة نبات الثندى. **المنهج:** وظفت عدة منهجيات في هذه الدراسة؛ مثل استخدام اسلوب الجمع الميداني للبيانات وذلك من خلال تقسيم مناطق المخيمات إلى شبكة من المربعات المتساوية، ومن ثم استخدام جهاز اختراق التربة المحمول لتسجيل قراءات انضغاط التربة، بالإضافة إلى أسلوب العد لحصر عدد نبات الثندى، وفي النهاية أجري تحليل للبيانات التي جمعت إحصائياً. **النتائج:** وجد أن انضغاط التربة في المواقع التي لا يوجد فيها مخيمات أقل بكثير من مواقع التخييم، وأن كثافة نبات الثندى أكبر بكثير في المواقع التي لا يوجد فيها مخيمات مقارنة مع مواقع التخييم؛ أما بالنسبة لعدد المربعات في كل مخيم، فقد وجد أن غالبية مربعات الشبكة تحتوي على كثافة عالية من نبات الثندى في المواقع التي لا يوجد فيها مخيمات وذلك على عكس مواقع التخييم. وباستخدام معادلة الانحدار اللوجيستي، وجد أن هناك علاقة عكسية ما بين انضغاط التربة ودرجة كثافة نبات الثندى. **الخاتمة:** اتضح من نتائج الدراسة أن التخييم يعتبر أحد أسباب انضغاط التربة، الذي يؤثر بشكل سلبي على كثافة نبات الثندى في صحراء الكويت.

المصطلحات الرئيسة: الكويت، الصحراء، التأثير الجيومورفولوجي البشري، التخييم، انضغاط التربة، نبات الثندى.

Evaluating Anthropo-geomorphic Impact of Camping on Cyperus Conglomeratus in Kuwait

Faisal Anzah*

Abstract

Objective: This research examined the indirect anthropo-geomorphic impact of desert camping—in the desert environment of Kuwait on Cyperus conglomeratus density. **Method:** Fieldwork data collection techniques were used in this study, such as dividing camps into quads, recording soil compaction readings by using a pocket penetrometer, implementing a counting method to count Cyperus conglomeratus, and carrying out statistical analysis to analyze the collected data. **Results:** It was found that undisturbed sites exhibited significantly less soil compaction than disturbed sites. The density of Cyperus conglomeratus was significantly higher in undisturbed sites compared to disturbed sites. It was also found that there was a high density of Cyperus conglomeratus in most undisturbed sites' quads, while they were sparsely available in disturbed sites' quads. The logistic regression model indicated that soil compaction was negatively associated with the degree of density of Cyperus conglomeratus. **Conclusion:** The findings showed that desert camping had had a significantly negative impact on soil compaction, reducing the density of Cyperus conglomeratus in the desert of Kuwait.

Keywords: Kuwait, Desert, Anthropo-geomorphology, Camping, Soil Compaction, Cyperus Conglomeratus.

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Research interests: Physical geography, Geomorphology, GIScience, Spatial statistics.

Introduction

Anthropogenic geomorphology, or anthropo-geomorphology, is the study of how humans can directly create or modify geomorphic landforms or can indirectly alter the operation of existing geomorphic processes. Worldwide, direct anthropo-geomorphic impacts may include, but are not limited to, mine spoil tips, mining and quarrying, and war-related craters (Szabó et al., 2010). These landforms are intentionally created by the actions of humans, each for a specific reason. In contrast, indirect anthropo-geomorphic impacts include, but are not limited to, deforestation (increasing the ability of water erosion), grazing (trampling causes soil compaction which will result in increasing soil erosion), urbanization and roads (causing channel sedimentation), and acidification of precipitation (increasing the rate of rock weathering). These actions create unintentional results, and their consequences are frequently more challenging to identify (Szabó et al., 2010).

Desert camping is a popular recreational activity and causes widespread indirect anthropo-geomorphic disturbances in many countries, including Kuwait. In the United States, there is a fortunate circumstance where campsites are geographically concentrated (McEwen & Cole, 1997). Therefore, camping exhibits a restricted spatial footprint. Additionally, its temporal impact is constrained, as campers often engage in camping activities for only a few days throughout the entire year. However, in nations such as Kuwait, Bahrain, and Qatar, and Saudi Arabia, located in the Middle East, where geographical features such as mountains, rivers, and forests are absent, the arid desert landscape remains the sole viable option to fulfill people’s desire to engage in camping activities. In the context of Kuwait, campgrounds are seen as residential spaces during the winter season, serving as temporary houses for individuals seeking refuge from the colder climate. Across the country, campsites are often established by individuals from the onset of November and then dismantled by the end of March. Throughout this period, people engage in the practice of regularly visiting and occupying their designated camping area, typically on weekends, for the purpose of overnight stays. Furthermore, certain individuals, irrespective of their occupations, choose to spend a significant portion of the winter season residing in their campgrounds. Thus, they commute daily from their designated camping areas to their respective places of employment. Two main factors lead to this camping practice: One is the limited geographical expanse of the nation, such that traversing the entirety of the country by automobile, either from its northernmost point to its southernmost or from its easternmost point to its westernmost, may be accomplished in around 90 minutes, assuming a constant velocity of 120 kilometers per hour; the other factor is the adoption of a more luxurious lifestyle. Campers often create elaborate living spaces resembling traditional indoor rooms, such as living rooms, bathrooms, shower facilities, kitchens, and beds, all inside the confines of their tents at the campsite. Furthermore, while campgrounds are common in the United States, they are not found in the State of Kuwait. Therefore, the potential geographical ramifications of campers' actions in Kuwait may be significantly more severe. In Kuwait, for example, it is possible for a single family to establish their campsite in varying locations every year, leading to soil degradation concerns on a broader spatial scale. Further, the potential temporal consequences could be significantly more severe due to the extended amount of time Kuwaiti campers often spend at their campsites compared to their American counterparts. Hence, it can be observed that camping activities in Kuwait and other Middle Eastern nations exert a significantly greater influence on the environment, since they lead to soil compaction on a greater scale and with a wider geographical coverage compared to such activities in Western countries (Anzah, 2019).

The practice of camping activities as a kind of recreational utilization of natural environments inevitably results in adverse effects on the ecosystem. The primary impact of camping activities on the soil is attributed to a process known as soil compaction, which occurs as a result of activities such as pitching tents and human trampling. This compaction subsequently leads to other various issues, including the reduction of soil moisture and organic matter, as well as diminished water infiltration (Grable & Siemer, 1968; Kemper et al., 1971; Williams & Brevik, 2010). These factors contribute to the process of land degradation. Soil compaction is recognized as a contributing factor to soil erosion, nutrient depletion, and pollution, all of which have been extensively discussed in various studies by the United Nations and other international organizations (Hartemink, 2008). The negative impact of soil compaction extends to various aspects of soil, including its physical, chemical, and biological characteristics and functions (Hakansson et al., 1988; Whalley et al., 1995). The process of altering the structure of soil involves the act of crushing aggregates or merging them together to form larger units. This process results in an increase in bulk density and a decrease in the number of coarser pores (Delgado et al., 2007; Horn et al., 1995; Needham et al., 2004; Richard et al., 1999; Wolkowski, 1990). The alterations mentioned above result in a decrease in water and air permeability (Douglas et al., 1998; Mooney & Nipattasuk, 2003), an increase in surface runoff and erosion (Schack-Kirchner et al., 2007), flooding, a decrease in groundwater recharge (Hamza & Anderson, 2005), and root depth limitation (Batey, 2000; Batey & McKenzie, 2006; Hettiaratchi, 1990; Pizer, 1990; Stone, 1988). The limitation in root depth eventually causes a reduction in vegetation. For instance, Marion and Cole (1996) studied the impacts of camping on soil and vegetation at Delaware Water Gap National Recreation Area and found that the trampling of campers significantly reduced the vegetation cover.

In Kuwait, various studies have been conducted on the impact of human activities on soil and vegetation (Al-Awadhi et al., 2003; Al-Dousari et al., 2000; Al-Dousari et al., 2019; Misak et al., 2002). However, none of these studies, except of Monsef and Abahussain's (2013) study, specifically and solely focused on analyzing the impact of soil compaction that is caused by human camping on the vegetation. Monsef and Abahussain (2013) studied the impact of camping on soil erosion using a modelling technique, but they did not consider exploring the statistical relationship between soil compaction and vegetation. Moreover, they used satellite images to extract a Normalized Difference Vegetation Index (NDVI) as an indicator or proxy of vegetation change.

The objective of the present study was to examine one of the most common anthropo-geomorphic activities—desert camping—in the desert environment of Kuwait and its impact on the density of Cyperus conglomeratus. Soil compaction was used as a proxy to identify the impact of camping on Cyperus conglomeratus density. In other words, this study evaluated the impact of the recently abandoned camps on soil compaction, and how soil compaction influenced Cyperus conglomeratus density which is considered a remarkable sand stabilizer (Omar et al., 2001) and important food for camels and sheep. To my knowledge, there are no published studies that have investigated the immediate impact of camping activities on soil compaction and on Cyperus conglomeratus density (as data collection was done immediately at the end of the camping season).

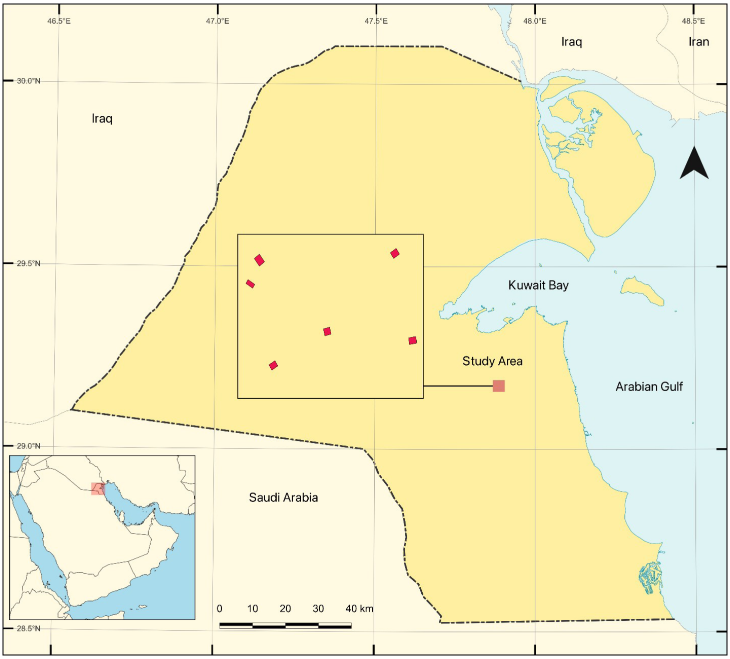
Method

Study Area

The study is conducted in the Bar AlJuwaihel area (29.14°, 29.19° N and 47.85°, 47.91° E), which covers about 35 km² and is a desert camping site located in the Mideast of Kuwait (Figure 1). Kuwait is a very small country with an area of about 18,000 km² and about 300 m of ground elevation range (Kusky & Cullen, 2010). Consequently, the climate is homogeneous across the country, including the study area. In July, the mean air temperature is about 38 °C, and the mean maximum air temperature is about 46 °C. In January, the mean air temperature is about 13 °C, and the mean minimum temperature is around 8 °C. Kuwait is considered a hyper-arid environment in which the mean annual rainfall is 119 mm and the mean annual potential evapotranspiration surpass 2270 mm. The annual rainfall ranges from 30 to 250 mm with the preponderance falling in the winter and spring seasons (Halwagy et al., 1982; Al-Sayegh, 2017). Winds predominantly blow from the northwest with the annual mean speed of about 14 km/h causing prevailing dust and sandstorms (Anzah, 2019).

Figure 1

Map of the Study Area



The desert of Kuwait supports a variety of desert plants. However, Cyperus conglomeratus (Figure 2) was the only plant that was found in the study area. Cyperus conglomeratus is a perennial desert plant that mainly colonizes sandy soil areas. The plant is about 60 cm tall with a dense cluster at the base. It is a remarkable sand stabilizer, as hummocks of fine sand grains are deposited on the leeward portion of the plant (Omar et al., 2001). The study area is a bare desert area that is dominated by extensive recreational camping, making it a good area for exploring the impact of desert camping on soil compaction and the spatial distribution of Cyperus conglomeratus.

Figure 2
Cyperus Conglomeratus

Data Collection

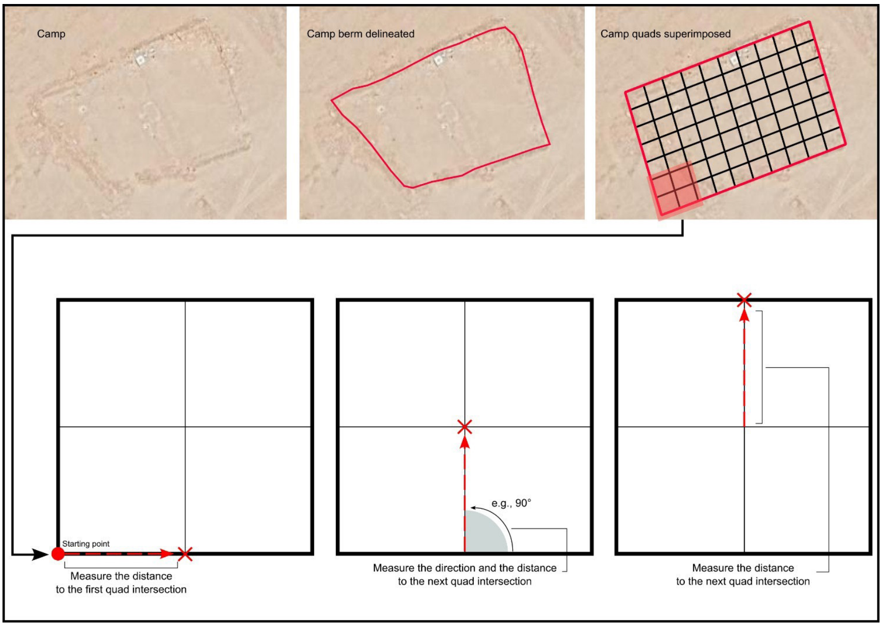
In the disturbed site, six camps were randomly chosen, and the borders of each camp were measured. To illustrate, using a tape measure, the north, south, east, and west borders of each camp were measured separately. The measurements were rounded to the nearest meter. Next, Google Earth Pro was used to trace and extract the borders of each camp. All extracted camps were exported as KML files and imported to QGIS. All extracted camps were projected into Transverse Mercator and the Minimum Bounding Geometry tool was used to superimpose a perfect rectangle on each site. Based on the length of the longest border on each of the opposite sides (the North and South sides), each border was divided into multiple segments. For example, if the length of the north border was 89 m and that of the south was 72 m, the north side of the perfect rectangle was divided according to the nearest tenth of the length of the longer berm (89 m was rounded to 90) and divided by ten (90/10 = 9 north/south divisions). The same was applied to the east and west sides. The segments were connected to the opposite side to create quadrats. This process is illustrated in Figure 3.

A map was created (Figure 3) for each camp using QGIS. The maps were printed for scaling and usage in the field as a guide. To precisely scale each map, the length of one border was measured in the QGIS layout view using the drawing tool and the printed sketch was scaled according to the length in the field and its length on the sketch. On the printed map, a protractor was used to obtain the bearing directions from a particular starting point to the next intersection point of the quadrat (north–south and east–west directions). The walking distances were also measured on the printed maps. All printed maps that had the bearing and walking distance information were used in the field as guides in dividing each site into quadrats

Two variables were collected in each quad within each site. These variables were soil compaction and the count of Cyperus conglomeratus. A pocket penetrometer (Figure 4) was used to measure soil compaction. Triplite measurements were recorded per quad. When facing low-strength cohesive sand, a foot adapter was attached to the penetrometer and the obtained measurements were divided by 16 to obtain unconfined compressive strength. Furthermore, counting techniques were used to count the number of Cyperus conglomeratus in each quad, and the count of Cyperus conglomeratus was divided by the quad area to calculate a new variable, Cyperus conglomeratus density. To understand the impact of anthropo-geomorphic activities on Cyperus conglomeratus density, the two variables were also measured on three undisturbed sites that were located 500–1000 m from the southern edge of the study area. The width and length of each non-disturbed site matched the average width and length of all disturbed sites, and the final shape of all non-disturbed sites was a perfect rectangle.

Figure 3

Illustration of the Process of Dividing Each Camp into Quads



Note. The sketch only represents a single camp.

Figure 4

The used pocket penetrometer

Statistical Analysis

As a first step, the two variables were checked for normality using the Shapiro–Wilk test. The test results showed that the soil compaction and the Cyperus conglomeratus density variables did not meet the assumptions of normality. Therefore, The Mann–Whitney U test was used to assess the difference in soil compaction and Cyperus conglomeratus density between disturbed and undisturbed sites, while Fisher's exact test was used to assess whether differences in Cyperus conglomeratus density level as a dichotomous variable (coded with 0 for no-low density and 1 for high density in each quad) were significant between the disturbed and undisturbed sites. Cyperus conglomeratus density was transformed into a dichotomous variable based on the median value, in which a median value that is <= 0.01 is considered as no-low density and >0.01 is considered as high density. Following Fisher's exact test, simple binary logistic regression was used to examine the relationship between soil compaction as a continuous independent variable and Cyperus conglomeratus density level as a dichotomous dependent variable. Statistical significance was determined by an alpha of 0.05 for all conducted statistical tests. All statistical tests were performed using IBM SPSS Statistics 25.0.

Results

The descriptive statistics of the studied variables are shown in Table 1; these clearly indicate that the disturbed sites have larger mean and median values in terms of soil compaction and lower values in terms of Cyperus conglomeratus density. However, to determine whether these results were statistically significant, statistical testing was applied.

Table 1

Descriptive Statistics for Soil Compaction and Cyperus conglomeratus Density Within Each Disturbance Level

	Disturbance Level		**Statistic**	**SE**
Soil Compaction	Disturbed Sites	M	3.226	0.0706
		Mdn	3.550	
		Variance	1.394	
		SD	1.1807	
	Undisturbed Sites	M	0.900	0.0619
		Mdn	0.500	
		Variance	0.736	
		SD	0.8578	
Cyperus C. Density	Disturbed Sites	M	0.00976	0.000223
		Mdn	0.00900	
		Variance	0.000	
		SD	0.003728	
	Undisturbed Sites	M	0.26220	0.010659
		Mdn	0.24200	
		Variance	0.022	
		SD	0.147696	

The result of the Mann–Whitney U test indicated that soil compaction in the undisturbed sites (Mdn = 0.50 kg/cm2) was significantly less than in the disturbed sites (Mdn = 3.55 kg/cm2) ($U = 4866.500$, $z = -15.144$, $p < 0.001$; Table 2). The test results also showed that Cyperus conglomeratus density in the undisturbed sites (Mdn = 0.242 plant/m2) was significantly higher than in the disturbed sites (Mdn = 0.009 plant/m2) ($U = 53728.000$, $z = 18.660$, $p < 0.001$; Table 2).

Table 2

Results of the Mann–Whitney U Test

Variable	Disturbance Level	
	Undisturbed	**Disturbed**
Soil Compaction (kg/cm2)	0.50***	3.55 ***
Cyperus conglomeratus density level (plant/m2)	0.242***	0.009***

Note. The values represent the medians of soil compaction and Cyperus conglomeratus density level at different disturbance level. *p ≤ 0.05. **p ≤ 0.01. ***p ≤ 0.001.

The results of Fisher's exact test indicated that there was a significant difference between the two sites in terms of Cyperus conglomeratus density in each quad disturbance level ($\chi 2(1) = 365.4$, $p < 0.01$; see Table 3). In the undisturbed sites, a low density of Cyperus conglomeratus was present in 36.9% of the total quad count, whereas a high density of Cyperus conglomeratus was present in 63.1% of the total quad count. In contrast, in the disturbed sites, a low density of Cyperus conglomeratus was spotted in 97.5% of the total quad count and a high density of Cyperus conglomeratus was spotted in only 2.5 % of the total quad count (Table3).

Table 3

Results of Fisher's Exact Test

Percentage of quad count	Disturbance Level	
	Undisturbed	**Disturbed**
Low density level of Cyperus conglomeratus (%)	36.9***	97.5***
High density level of Cyperus conglomeratus (%)	63.1***	2.5 ***

Note. *p ≤ 0.05. **p ≤ 0.01. ***p ≤ 0.001.

Finally, the logistic regression model was statistically significant, $\chi2(1) = 286.276$, $p < 0.001$. The model explained 62.7% (Nagelkerke R2) of the variance in Cyperus conglomeratus density and correctly classified 85.4% of cases. Therefore, it could be concluded that the increase in soil compaction was negatively associated with Cyperus conglomeratus density. To illustrate, a one-unit increase in soil compaction will cause the odds ratio (Wald = 144.060, $p < 0.001$) of Cyperus conglomeratus being highly dense in a quad to decrease by 76.8% (1 – Exp(B)) (see Table 4).

Table 4

Results of the Logistic Regression Model

Term	Coefficient	Wald	df	p-value	Exp(B)	95% CI
Constant	2.045	78.833	1	0.000	7.727	7.727
Soil compaction	-1.462	144.060	1	0.000	0.232	(0.183, .294)

Discussion and Conclusion

This paper investigated the indirect geomorphic impact of humans on soil compaction and how this affected the spatial distribution of Cyperus conglomeratus. As with other studies (Al-Houty 2009; Monsef & Abahussain 2013), our results showed that camping activities significantly impacted soil compaction, which was expected. This negative impact is caused by the trampling of campers and the overlying of tents over the sandy surface soil for several months. Regarding the density of Cyperus conglomeratus, our results also showed that the vegetation density was much higher in the undisturbed sites. In the western region of Saudi Arabia, Fakhry and Aljedaani (2020) concluded that 76% of the perennial species in the study area disappeared because of the human impact on Cyperus conglomeratus. The result of the logistic regression model suggests that soil compaction has a significant negative impact on the density of Cyperus conglomeratus such that quads which have uncompacted soil support the greater abundance of Cyperus conglomeratus. This can be attributed to soil compaction being a lead factor in decreasing soil pore space, which results in a reduction of water infiltration (Douglas et al., 1998; Mooney & Nipattasuk, 2003) and root penetration (Marion & Cole, 1996).

Desert camping is a widespread and popular anthropo-geomorphic activity in Kuwait. The indirect anthropo-geomorphic impact of desert camping is a major environmental concern that has been proven to reduce the native biota. The present study was limited, however, in that it only examined a small area of desert. Therefore, studying the geomorphic impact of camping on different locations that have different biota is essential for a comprehensive understanding of this phenomenon. A comprehensive understanding of the phenomenon will lead the authorities to take the best actions to mitigate such an impact.

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