الخصائص الطبوغرافية وتقدير كمية الحصاد المائي في قاع الجفر

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الجغرافيا الطبيعية التطبيقية

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المملكة الأردنية الهاشمية

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مستخلص. يُعد قاع الجفر التكتوني الأكبر في هضبة الأردن الجنوبية، ويحتل الجزء الأوسط من محافظة معان، وتبلغ مساحته ١٢٤٠٠ كم²، يشكل ما نسبته ٣٧,٧٪ من المساحة الكلية لمحافظة معان البالغة ٣٢٨٣٢ كم². وقد تشكل هذا الحوض نتيجة لسلسلة من الحركات التكتونية. وتُعد ظاهرة القيعان، ومناطق الانتشار المائي من أهم الأشكال الأرضية التي تميزه. والأهداف الأساسية لهذه الدراسة تمثلت في تحليل الخصائص الطبوغرافية، وتأثيرها على أنماط الأشكال الأرضية، وتقدير كمية الحصاد المائي في هذه المنطقة. وتم اشتقاق القيعان اعتماداً على الخريطة الطبوغرافية بمقياس ١: ٥٠٠٠٠، والصورة الفضائية لعام ٢٠١٨ وجاءت أبرز النتائج كما يلي: (١) - تميز التوزيع الجغرافي للقيعان بالتركز في ثلاثة مناطق أساسية، على الرغم من انتشار القيعان على مساحة نسبته ٥١٪ من مساحة منطقة الدراسة. (٢) - تم اشتقاق ٤٦٢ قاع جاف بمساحة قدرها ٤٢٢,٢ كم²، والتي تُشكل ما نسبته ٣,٤٪ من المساحة الكلية لمنطقة الدراسة، مع وجود اختلافات ذات دلالة في مساحاتها ما بين المساحة الصغيرة جداً حوالي ٩٨٨ م² إلى الأكبر مساحة والمتمثلة بقاع الجفر والبالغ مساحتها ٢٥٠,١ كم². (٣) - أوضحت نتائج التحليل المكاني للقيعان أنها تتركز في المناطق ذات الارتفاعات ما بين ٨٣٣-١٠٤٧ م وبمتوسط ارتفاع ٨٦٨,٦ م، وانحدار تراوح ما بين ٠-١٣°. Thiessen polygon method (٤) تقدير معدل الأمطار المساحية الموزونة اعتماداً على نموذج معدل الأمطار للعام المطري ٢٠١٦/٢٠١٧ حوالي ٦٠٩٧,٣٩٣ ملم، ومعدل عمق المياه في كافة القيعان حوالي ١٣٠,٢٥٥ ملم خلال تلك السنة. الكلمات المفتاحية: أحواض القيعان ، النقاط الساخنة، نموذج ثيسون للمضلع، الحصاد المائي.

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Table 8. The results of Thiessen Polygon analyst

Stations	Annual Rainfall in mm	Area in km ² and Percentage	Total weighted rainfall in mm	Mean depth of rainfall in mm
1	22	7874 (63.5%)	173228	22.1
2	25	2604 (21%)	65100	25
3	121	186 (1.5%)	22506	121
4	17	1054 (8.5%)	17918	17
5	310	682 (5.5%)	211420	310

Figure 6. (A). Thiessen Polygon analysis for 5 representative stations. (B). Thiessen Polygon analysis for 462 of (PB). (C). The density distribution of the mean depth of rainfall in mm.

5. Conclusion

The comprehensive analysis of the study area was carried out in terms of the spatial distribution of the unique geomorphological landform (the playa basins), in an area characterized by a hyper-arid zone in Jordan. The results indicated that the highly clustered distribution and the number of (PB) varied according to the data source. There are approximately 462 (PB_s) with a total area of 422.2 km², based on the topographic map, while the (PB) number reached 556 with a

total area of 436.4 km² based on the Landsat 8. The spatial distribution of (PB) is strongly related to the low elevation and slope. Average total rainfall estimates for the (PB) based on the Thiessen Polygon method were calculated. The deposits as lake sediments introduced by streams or wind from the surrounding plains resulted in the low mean depth for all the (PB), which is estimated at 47.5 (mm). Consequently, these landforms (PB) are the best sites for water harvesting.

Table 7. Soil and geology types beneath the (PB)

Soil type	Area (km ²)	Percentage (%)
Gently undulating limestone plateau	346.8	81.5
Major wadis with associated depositional basins	11.9	2.8
Very gently undulating plains on limestone	4.4	1.2
Very gently undulating, rocky, basalt plain	59.3	14.5
Total	422.4	100
Geology type	Area (km ²)	Percentage (%)
Sandstone	0.1	0.02
Quaternary	96.5	22.8
Qa'a	309.3	73.3
Limestone	16.5	3.9
Total	422.4	100

Figure 5. The Soil and Geology Maps beneath the (PB)

4.5. Estimating the rainfall harvesting and natural recharge to groundwater

Water harvesting in such a hyper-arid area is essential, where rainfall is rare and there is uneven distribution throughout the rainy months. The amounts of water harvested can be used for watering cattle and recharging the groundwater (De Winnaar et al., 2007). The Thiessen Polygon method has been used to estimate the annual rainfall data in many studies (Chidley & Keys, 1970; Powell, et al., 2014). Estimation of areal precipitation from points precipitation measurement was conducted (Spatial analysis tools). A five-station network of point measurements was used to estimate the true volume of water over

a given area. Network precipitation measurements were converted to real estimates using the Thiessen Polygon, approach, which calculates station weights based on the relative areas of each measurement station in the Thiessen Polygon network. The individual weights are multiplied by the station observation and the values are added up to obtain the areal average precipitation figure 6. (A). In addition, the average depth of precipitation is calculated. Thus, a point layer generated to represent the center of each (PB), then, the value of each (PB) extracted from the base map, and then the Thiessen Polygon method was applied again, Figure .6. (B).

(LULC) in the study, area was extracted by digitizing on screen from the Landsat 8, utilizing Landsat satellite images for the years 2018 of the study area. The land use/cover in the study area is for agricultural land 0.16%,

bare land 99.39%, urban and built-up area 0.34% with high concentrated in the western part (highland) of the study are, and water bodies 0.112%, figure 4 (C).

Table 5. Land use classes and definitions used in this study

Classes	Area (km ²)	Percentage (%)	Definitions;
Built-up area	41.8	0.34	41 villages, roads with 15km ² , King Faisal Airbase
Water bodies	13.9	0.112	All areas of open water, including streams, spread water and non-perennial/intermittent/fluctuating
Vegetaion and irrigated area	20	0.16	irrigated lands mainly under plastic houses, and areas of sparse vegetation cover.
Bare land	12324.4	99.39	Bare rock areas, gravels, stones and boulder areas, and hardpan areas, basalt

4.4. Geology and soil

The amount of water harvesting and groundwater recharge are controlled mainly by geology, soil characteristics and depth of the water table. Low-permeable soils represent the best sites for water harvesting rather than recharge of the groundwater. The western part of the study area is mainly of carbonate rocks with very good water quality. While in the eastern parts, it is confined by overlying thick impervious argillaceous unit of the Muwaqqar Formation (Sharadqah, 2014).

The results of the soil and geology maps show that the mean depth of rainfall beneath the (PB) is varied and reflect the soil and geology properties, and can be summarized as follows (Table 6 and Figure 5):63.5% from the total area of (PB) with a mean depth of rainfall 22.1 mm, which are clustered in the center of the study area. 21.5% of the total area of (PB)

with a mean depth of rainfall 121 mm.Only 5.5% of the total area of (PB) with a mean depth of rainfall ca. 310 mm, which is randomly, irregularly distributed in the study area, with the highest annual rainfall in the Western Highlands of the study area which enjoys a Mediterranean climate, and permeable soils represent the suitable sites for groundwater. By contrast, the southeastern corner of the catchment area has a lower amount of recharge due to impermeable soils (Al Kuisi & El-Naqa, 2013). These results confirm the importance and characteristics of the (PB) as the best sites for water harvesting, rather than recharge groundwater, especially with the decline of groundwater levels due to excessive pumping ;as the groundwater level declines in the study area ranging from few meters up to 165m (Sharadqah , 2014).

Table 6. Playa basin density in the study area

Depth in mm	Area (km ²)	Percentage
0.1 - 43	1624.4	13.1
43.1 - 57.4	3211.2	26.3
57.5 - 70.9	6292	50.5
80 - 95.2	974.8	7.7
95.3- 137.9	297.6	2.4

Table 3. (PB) density in the study area

Density	Area (km ²)	Percentage (%)
0-43.3	10143.2	81.8
43.4-57.4	1215.2	9.8
57.5-70.9	620	5
71-95.2	297.6	2.4
95.3-137.9	111.6	0.9

Table 4. The results of the (OHS) analysis according to StdResid value

(PB)-Classes	Number	LocalR2	StdResid
$\geq 1\text{km}^2$	29	0.033767	2.78913
0.1-0.91km ²	217	0.0237687	0.40373
$\leq 0.1\text{km}^2$	298	0.0235822	-0.3289

Figure 4. The spatial distribution (SD) of (PB), according to spatial statistical (OHS) methods, and the (SD) of (PB) according to its areas in km², respectively. Land use in the study area, extracted by digitizing on screen from the Landsat 8.

Qa'a Al-Jafer covers almost 250.1 km², and has attitudes of between 833M, which represents the largest (PB) occupying the

lowest point in the depression Qa'a is carpeted by fine and very fine sediments, the characteristics of a sabkha, without vegetation, figure 4.(C), flooded in wet periods and covered at other times by salt encrustations.

4.3. Land use/cover (LULC) in the study area

Table 2. (PB) results from both sources

ID based on area TM	Number	Area (km ²)	Percentage (%)	Rainfall in mm	Weighted depth of rainfall in mm	Mean depth of rainfall in mm
Qa'a - Al-Jafer	1	250.1	59.3	138.37	10441.64	40.99
1-19km ²	31	100.217	23.7	1730.35	6149.43	173.58
<1km ²	430	71.7508	17	28511.15	4129.04	46.44
Total	462	422.068	100	252.6	10867.22	3024.23
ID based on area (Landsat)	Number	Area (km ²)	Percentage (%)	Rainfall in mm	Weighted depth of rainfall in mm	Mean depth of rainfall in mm
Qa'a- Al-Jafer	1	254.716	58.4	148.37	15441.64	276
1-19km ²	27	106.294	24.3	58.22	408.2	110.2
<1km ²	528	75.3156	17.3	54.01	14.41	134.32

4.2. The spatial distribution of (PB)

(PB) were extracted from the both sources a topographic map 1:50000 scale, and Landsat-8 by digitizing of all kinds of (PB) on screen, then Optimized Hot Spot (OHS) methods analysis was employed to monitor if the (PB) clustered based on the z-scores and p-values and confidence level bin (Gi_Bin) for each input (PB) in the dataset. This tool identifies the clusters of complications with high values (hot spots) and clusters with low values (cold spots) (<http://pro.arcgis.com> ; Getis & Ord, 2010; ArcGIS 10.5, tool help). The local sum of the complication and its neighbors is compared relatively to the total sum of complications. The (PB) were distributed into three spatial patterns according to the topography, location and size: random, irregular, and clustered patterns. Table 3

summarizes the results of the (OHS) analysis, with no significant differences according to the data sources (TM and Landsat -8).

The z-scores and p-values returned by the pattern analysis tools tell whether we can reject the null hypothesis or not (The playa basins are not clustered). When the p-value is very small, meaning that the observed spatial pattern is the result of randomness (Achar et al., 1998). The relationships between playa size, density, and their pattern distribution on the study area (Figure 3) indicated that 90% of the total area of (PB) is highly clustered in the lowest elevation and slope in the center of study area and its origin tectonic. (PB) density increases from north to the center (Figures 2-4 and Table 3), with (PB) highly clustered patterns.

platform representing shallow to deep marine carbonates and marls (Edgell, 2006; Ziadat et al., 2012; Powell et al., 2014). Multiple horst and graben structures with strong vertical displacements are exposed along the northern boundary of the Al-Jafer Basin and are controlled by the Karak-Wadi al-Fiha fault system (Bender, 1974). The Quaternary sediments of the study region are mainly underlain by the Muwaqqar Chalk-Marl Formation of Maastrichtian to Paleocene age. Apart from limestone and chalk of the Eocene, there is an Umm Rijam Chert Limestone formation in the north and northwest of the Al-Jafer Basin. The Jafer Formation comprises alluvial to lacustrine conglomerates, silts, marls and carbonates regarded as calcretes (Bender, 1974). Figure 4 shows the soil and geology maps. In addition, unconsolidated Aeolian sediments occur in the Al-Jafer Basin (Bender, 1974). Exposures in the adjacent region of the basin are characterized by Mesozoic and Cenozoic chalk, marl, bituminous and silicified limestone, phosphorite and chert. Modern sediment

dynamics in the basin are dominated by wind erosion and accumulation of Aeolian deposits. Multiple horst and graben structures with strong vertical displacements are exposed along the northern boundary of the Al-Jafer Basin and are controlled by the Karak-Wadi al-Fiha fault system (Bender, 1974). The study area is characterized by hyper-arid climatic conditions with a mean annual precipitation <100 mm resulting from the rain shadow effect of the western escarpment of the Jordan Plateau (Al Kuisi & El-Naqa, 2013). Rare precipitation occurs during winter months between December and March. Following rain events, a water body with a maximum depth of one meter can cover the playa center for more than one month.

4.1. (PB) extracted

(PB) were extracted from the two sources: a topographic map 1:50000 scale and the Landsat -8 by digitizing of all kinds of (PB) on screen, as shown in Figure 3 and Table 2. (PB) are the unique geomorphic features in the study area.

Figure 3. (A) The spatial distribution of (PB), extracted by digitizing on screen from the TM and (B) The spatial distribution of (PB), extracted by digitizing on screen from Landsat 8.

36) and WGS84 ellipsoid. Then Landsat 8-OLI was used to extract (PB) for comparison with results based on (TM), and a Land use/cover-generated map, Figure 3.

3. 3. A geology map: was obtained from the Natural Resources Authority <http://www.jordansun.com/>.

3. 4. Soil map: obtained from Ministry of Agriculture, Jordan (Ministry of Agriculture, 1995).<http://moa.gov.jo/ar-jo/>

Table 1. Slope and elevation of the study area

Slope by degree	Area (km ²)	Percentage (%)	Elevation (m)	Area (km ²)	Percentage (%)
0 – 4	4736.8	38.2	795-946	7365.6	59.4
4.1-7	4960	40	947-1106	2901.6	23.4
7.1-12	2182.4	17.6	1107-1331	1388.8	11.2
12.1-61	520.8	4.2	1332-1735	744	6

Figure 2. The location of the study area within Ma'an Governorate by elevation (m), Slope by degrees, and (PB) density (after conversion from polygons to points).

3. 6. Rainfall data: Average annual rainfall data was collected from five stations distributed throughout the study area for the hydrological year of (2016/2017) for each station was calculated. The location of the stations is shown in Figure. 4. Then the Thiessen Polygon (TP) method was applied in many studies (Thiessen, 1911; Chidley and Keys. 1970; Anctil et al., 2006). (TP) is a simple method created to obtain the average rainfall in large areas. It is frequently used and

3. 5. Aster DEM: (Advanced Space-borne Thermal Emission and Reflection Radiometer) with horizontal resolution of 30 meters was downloaded for the study area from <http://asterweb.jpl.nasa.gov/>. The DEM was processed to prepare elevation and slope of the study area. Elevation and slope classify into four categories of elevation and slope, Figure 2.

its formulation consists in determining a weighted average with rainfall amount of each station, in which weights are determined according with the influence area of each station. In this case, (TP) was prepared using interpolation tools in Arc GIS to convert the rainfall data from a points map to a spatial map, using the Geostatistical Analyst. The total area for each polygon was computed, and the weighted depth of rainfall was computed as; rainfall in mm*area of each polygon of (PB) in km².

4. Results and Discussion

The Jordan Plateau is part of the Upper Cretaceous to Paleocene Arabian carbonate

decreases from 150-250 mm in the Western and Northwestern Highlands to less than 50 mm in the East. This illustrates the rain shadow effect of the Western Highlands. The mean annual rainfall for the Al-Jafer Basin was estimated to be 53.6 mm between 1976

and 2005 (Mischke et al., 2015; Ibrahim, 1996.). The central part of the basin is occupied by the largest dry playa (Qa'a Al-Jafer), covering an area ranging from 250.1 km² based on the topographic map to 254.7 km² based on Landsat -8.

Figure 1. The location of the study area within Jordan, and the main faults affects the study area.

3. Data Sources and Methodology

3.1. Topographic Map: Forty-eight topographic plates at a scale 1:50,000 generated by the RJGC (Royal Jordanian Geographical Center, 1991), cover the study area, as shown in Figure. 2. The topographic map (TM) was scanned and converted into a digital format at 300 DPI jpg format, The 48 topographic plates were georeferenced using known coordinates for the four corners of each map sheet, with a mean of RMSE 0.000312030, rectified and georeferenced to

JTM map projection (Zone 36), and WGS84 ellipsoid. They were mosaicked using data management tools, and masked using Arc Toolbox, cartography tools (masking tools), and then were digitized in various types and sizes of (PB) using ArcGIS software (Al-husban, Y., 2017).

3. 2. Landsat Image: Landsat 8-OLI for the year 2018 with a ground resolution of 30*30m was obtained from the (USGS) United States Geological Survey (<http://glovis.usgs.gov/>). The digital image was geometrically and radio-metrically calibrated to each other to facilitate their comparison, rectified and georeferenced to UTM map projection (Zone

1. Introduction

A playa is defined as the flat-floored bottom of an untrained desert basin that turns into a shallow lake during rainy months; evaporation leaves a deposit of salt or gypsum (Bolen et al., 1989; Bourne & Twidale, 2010; Casula, 1995). (PB) forms one-third of the land of the earth (El-Baz, 1988). Basins of interior drainage are common in Jordan, they are numerous and widely distributed in the south-eastern and the southern regions, Specifically in Al-Mafraq and Ma'an Governorates (Topographic map, 1991; Allison, and Grove 2000). The (PB) have evolved in various ways; small ones have been formed by wind and the low elevation and slope, while the major large basins evolved by tectonic and faulting activity (Al-Homoud et al., 1998; Haukos & Smith, 2003). In this paper, we define the (PB) based on their geological, geomorphological settings and the associated tectonic and faulting activity. All (PB) are located at low points of altitude and low slope (DEM). This distinctive landform pattern was studied based on the topographic map, and Optimized Hot Spot (OHS) analysis, using Spatial Statistics in (Arc GIS). The (PB) were distributed into three spatial patterns according to their physical factors: random, irregular, and clustered pattern. Optimized Hot Spot methods analysis was used in a range of different studies. Hot Spot analysis calculates the Getis-Ord Gi statistic for all the complications in the data (Getis & Ord, 2010; Achard et al., 1998). The Calculated Z score indicates which part of the data is clustered into small and large values. This tool identifies the clusters of complications with high values (hot spots) and clusters with low values (cold spots) (<http://pro.arcgis.com>). Estimates on the number of (PB) in the study area vary from 462 based on the TM (topographic map at a scale of 50,000), extending to 565 (from Landsat 8-OLI). The playa areas are classified

into three categories according to the area in km²: (1)- the largest playa is Qa'a Al-Jafer, which comprise ca. 250.1 km² and 59.3% of the total area of all (PB). (2)- (PB) with an area between 1 km² to 19 km², which comprise 100.2 km² and approximately 23.7% of the total area. (3) -The remainder of (PB) with areas of less than 1 km², which form 71.6 km² or some 17%. Historically, the (PB) were the most suitable locations for water harvesting and water available during the winter season (Allison et al., 2000). Several studies dealing with Jordan's arid and semi-arid land focus on water harvesting and recharge of groundwater (Howard, 1984; JICA, 1990; Al Kuisi & El-Naqa, 2013; El-Naqa, 2010), but none of these studies mention the role of (PB) as natural phenomena for water harvesting. Thus, one of the aims of the present study is to estimate the amount of areal rainfall beneath the (PB), using the Thiessen Polygon method.

2. Description of the Study Area

Al-Jafer Depression (Basin) is located in the southern area of Jordan (Governorate of Ma'an), Figure 1. It is an area of some 12,400 km², extending from 29° 30' to 30° 30' N and 35° 30' to 37° 00' E. The majority of the Basin area, 90%, is classified as hyper-arid land with less than 50mm/ year. The drainage pattern is almost radial from the encircling Western Highlands towards the central Qa'a Al-Jafer Mudflat area. Ground elevation ranges between 795 m in Al-Jafer Playa to ca. 1,735 m in the Western Highlands, while the mean elevation of the basin is 1,265 m. 78.2% of the total area has a slope degree below 7°, and 82.8% of the total area has an elevation between 795 m and 1106 m, with relief only 311 m. Al-Jafer Basin is 150 km long (NW-SE) and approximately 100 km wide (topographic map). The Western Highlands area of Al-Jafer Basin is of special importance because it is practically the recharge area for the whole Al-Jafer Basin. Precipitation

Topographic Characteristics and Estimation of the Quantity of Water Harvesting in Al-Jafer Depression

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Abstract. Al-Jafer depression is the largest tectonic depression in the Southern Jordan Plateau. It occupies the central region of Ma'an Governorate. Covering area of ١٢٤٠٠ km², consisting about 37.7% of Ma'an area Governorate (32832km²). The basin was formed by a sequence of tectonic and faulting events and the most important patterns of Landforms are the Playa Basins (PB) and water spread. The main goals of this paper are to monitor the topographical characteristics and the impact of these topographical characteristics on landforms patterns and estimating rainfall harvesting. Based on a Topographic map at scale 1:50,000. findings indicated that the: (1) - (PB) area highly clustered distributed in three main zones, although the (PB) are geographically distributed over 51% from the total area of Al-Jafer depression (2) - There are approximately 462 dry (PB_s) with a total area of 422.2km², which forms 3.4% from the total area with significant variation in its areas from a small area about, 0.988 m², to the largest one 250.1 km² (Qa'a Al-jafer). (3)- The spatial distribution of (PB) are very much related to elevation and slope; which ranges between 833m to 1047, with mean of elevation 868.6m and standard deviation 36.2. The (PB) distributed within slope degrees between 0°-13°. (4)-average total rainfall estimates for the (PB) based on Thiessen polygon methods. The total weighted rainfall about 6097.393(mm / hydrological year of (2016/2017), and Mean depth of rainfall in mm (PB) is 130.255(mm).

Key words: Blaya Basins, (Qa'a), Optimized Hot Spot, Thiessens Polygon Method, rainfall harvesting.

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