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الجيومورفولوجيا الحضرية لمدينة دهوك

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Urban Geomorphology of Duhok city

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Abstract:

The area of Dohuk city in 1967 was 1.0 km^2, and then it expanded until it reached 6.94 km^2 in 1987, then 41.64 km^2 in 2022, and thus it extends over 12 geological formations. the city extended upon 12 various, heterogeneous formation and sedimentation which have different response to geomorphic processes, slope deposit consisting highest area 46.9 km^2, lowest formation area is Aliji formation 2.6 km^2, Mountains encircle the City from all directions except the west, Baikhair mount from the North, Dohuk mount from south, Mamsin from East, elevation of area between 1100 - 440m, Slope degree is between 0 - 87.9°. There are 6 Geomorphic units, and the highest unit area is Alluvial fan 63.84 km2, lowest unit area is a flood plain 2.94 km2. The extension of the city in 1967 was limited for two geomorphic units, the floodplains and the accumulative glacis, in 1987, The city extended to new geomorphic units, which are fluvial fans, and in 2022, the city expanded to the previous geomorphic units, in addition to its extension on geomorphic units with higher elevations and slopes than its formers, which are 545the pediments and mountains. Finally, the results of urban geomorphology studies can be taken into account in the context of systematic and comprehensive scientific planning rather than the random and ill-considered expansion of the city.

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Introduction

Iraqi cities, including Dohuk, suffer from a lack of planning, is one of the cities that have a distinct characterized by the presence of a special, various landforms, this city witnessed high rates of urbanization ,This requires knowing the land units that exist and surround the city of Duhok, which determine the shape of the city and draw directions for its expansion. so this study highlights the expansion of the city, which means a road map for planners and decision-makers to contribute In developing a future plan of the expansion of the city, the results of this expansion on the city and on different axes leads to the impact on the landforms, thus determines in the future the impact of operations by this expansion and will reflect the impact of geomorphic processes by this human act and will negatively effect on the city in future, i.e. each unit have its particular processes. The growth and development of a city over the years are steadily altering the local topography. Ultimately, such changes impact geomorphic processes such as weathering and erosion [(1)]. Therefore, it must be taken into account when planning cities the conditions surrounding cities, especially the landforms, as they represent the space on which the city expands in the future, so attention must be paid to this topic because there will be many problems if they are not planned, for example, pass a limit of agricultural land and converting it into residential land, as well as random, unorganized and unplanned expansion leads to encroachment on river basins and thus causes many problems, including Deterioration of water quality ,erosion processes, increase of impermeable surface areas and thus increase the frequency of floods.

2.Study area

Duhok city is located within a physical geographical framework that affects the morphogenetic of the city mainly, as it is surrounded by mountains by three sides, north Al-Abedh, east Mount Mam Sin and the south Zawa, , while from the west it opens to the plain of Semil, which represents the only the areal outlet that allows the expansion of the city, and the rivers of Duhok and Heshkarow pass through it Both rivers meet up in the southwest of the city, its located between latitude 36°50´0"- 36°55´0" N and longitude 42°55´0"-43°5´0" E figure(1) .

As the surrounding mountains are of relatively high altitudes, the climate is similar to that of the climate of the Mediterranean region which is characterized by dry summers and winters with reasonable precipitation. The summer is hot with low humidity and bright sunshine. In contrast, winters have a noticeably higher humidity and lower temperatures. While in the winter season, the climate is characterized by its low temperatures and snowfall in the high mountains. Occasional drought seasons that are repeated periods of time lead to an underground water recharge deficiency. A significant amount of rainfall and temperatures are rising characterizes the spring season [(2)].

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Figure (1) Location of study area

Months with the largest precipitation are April, March, May with 152 mm precipitation. Most precipitation occurs in April with an average precipitation 55 mm. The annual amount of precipitation in Dohuk is 409 mm. The average annual temperature is 15°C in Dohuk. The warmest month of the year is August, with an average temperature: 28°C. Usually, January is the coldest months in Dohuk, with average temperature 2°C. The difference between the hottest months: August and the coldest months: January is: 26°C. The difference between the highest precipitation (April) and the lowest precipitation (August) is 45mm [3] [4] Figure (2).

Figure (2) Average precipitation and Temperatures 1938-2018

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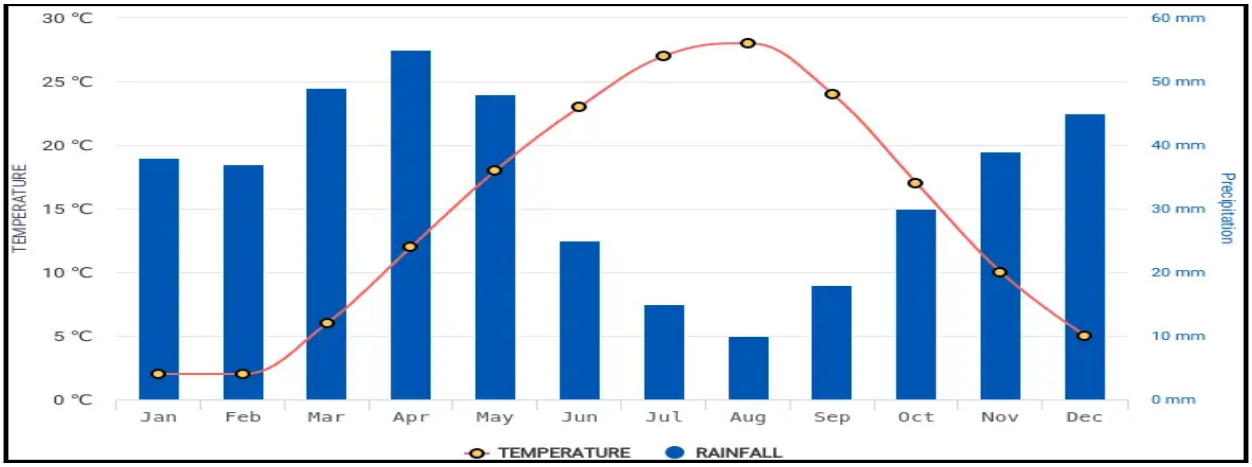

(Hikersbay.com/climate/Iraq/dihok)

3. Geological characteristics

The Geology of the study area consisting 12 geological formations range from the upper Jurassic (Upper Mesozoic) represented by Chia Gara formation to the Quaternary sediments represented by the deposits of the slopes dating back to the Pleistocene, The formation Chia Gara is exposed only in the Eastern-north limb of Zawita anticline with (3.075km2) while Slope deposits occupying (46.960km2) the highest area in study area, The slope deposits consist mainly of limestone and dolostone rock fragments, poorly cemented by sandy, silty and calcareous materials. Locally, they are well cemented and very hard. Some large rock blocks (more than one meter) could also occur within these deposits. The thickness of these deposits is highly variable, it ranges from less than 1m up to 15-20m.But usually it is about 1.5 - 5.0m [5], Table (1) figure (3).

Table (1) Geological formation for Duhok city

Nu.	Geological formation name	Area(km^2)	formation
1	Chia Gara	3.075	Shale -Limestone (locally bituminous)
2	Aqra	13.491	Massive and bedded Dolostone - Limestone
3	Khurmala	3.241	Dolostone - Limestone
4	Aliji	2.637	Shale-Marl-Limestone-Sandstone
5	Gercus	43.670	Red clastic
6	Pilaspi	22.254	bedded Dolostone - Limestone
7	Fatha	4.353	Claystone-Marl-limestone-Gypsum-Siltstone
8	Injana	10.718	Claystone-Sandstone -Siltstone
9	Terraces deposits	2.757	Conglomerate-lenses of sand-silt-rare clay
10	Slope deposits	46.960	Rock fragments-sand--silt slightly cemented
11	Residual soil	4.025	Sandy and loamy soil, locally gypsifariouse
12	Dohuk lake deposits	19.096	Gravel-sand -silt-clay
Total		176.2	

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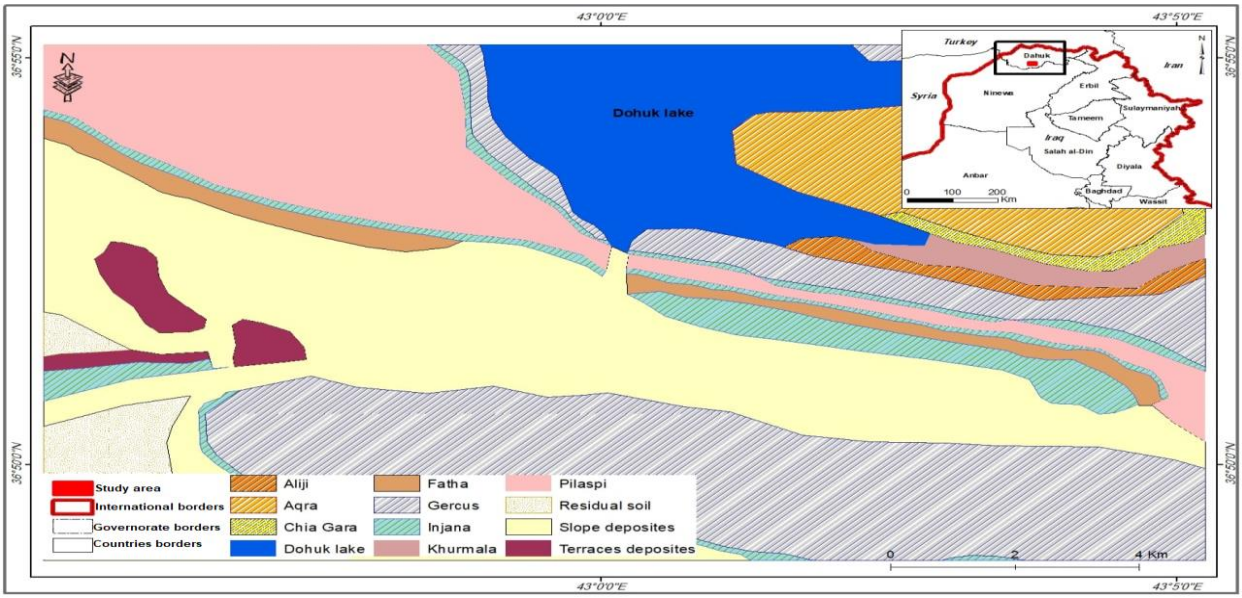

Figure (3) Geological formation

4. Material and methods

4.1. Data Sources

A multi- data used in this research. Among its Landsat-9 OLI_TIRS satellite image, SRTM 30m Digital Elevation Models, meteorological data, land use data, and administrative division data. All data sources are shown in Table (2), figure (4).

Table 2. Data Sources for study area

Data	Time	Format	Source	Resolution
Landsat-9 OLI_TIRS	2022	Raster	https://earthexplorer.usgs.gov	30 m _ 30 m
Landsat 5 (TM)	1986	Raster	https://earthexplorer.usgs.gov	30 m _ 30 m
CORONA/Satellite	1967	Raster	https://corona.cast.uark.edu/	2m
DEM (SRTM GL1)	2000	Raster	https://portal.opentopography.org	30 m _ 30 m
3D model	2023	Image-jpeg	https:// 3d-mapper.com	-
Meteorological data	1938-2018	text	Hikersbay.com/climate/Iraq/dihok	-
Bing satellite image	2022	Raster	https://www.bing.com/maps/	30 m _ 30 m
Google earth-pro	2004-2021	Raster	Software	50m
Topographic map	1986	digital	General directory of survey	-
Administrative division	2020	Shapefile	Administrative Iraq map	-

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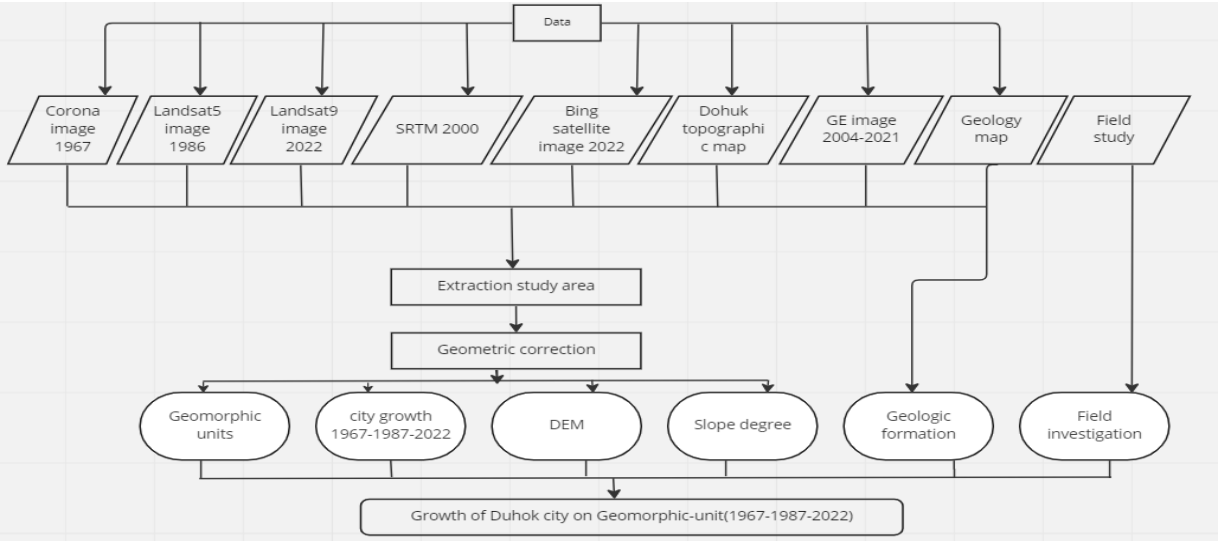
Figure (4) flow chart for methodology and data processes



Results

The elevation of the area is ranging between 1100 meters in the mountains unit and 440 m in the floodplains figure (5) and the city is confined between mountain ranges surrounded by all sides except the western side, the northern mountains Spirez,Abedh and Baikhair, from east mamsin mount and southern mount of Dohuk and Zawa figure (6) with limited floodplains in the region, the city spread and expanded on all geomorphic units and even on the highest of them, which are represented by the mountains.

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figure (5) DEM of study area

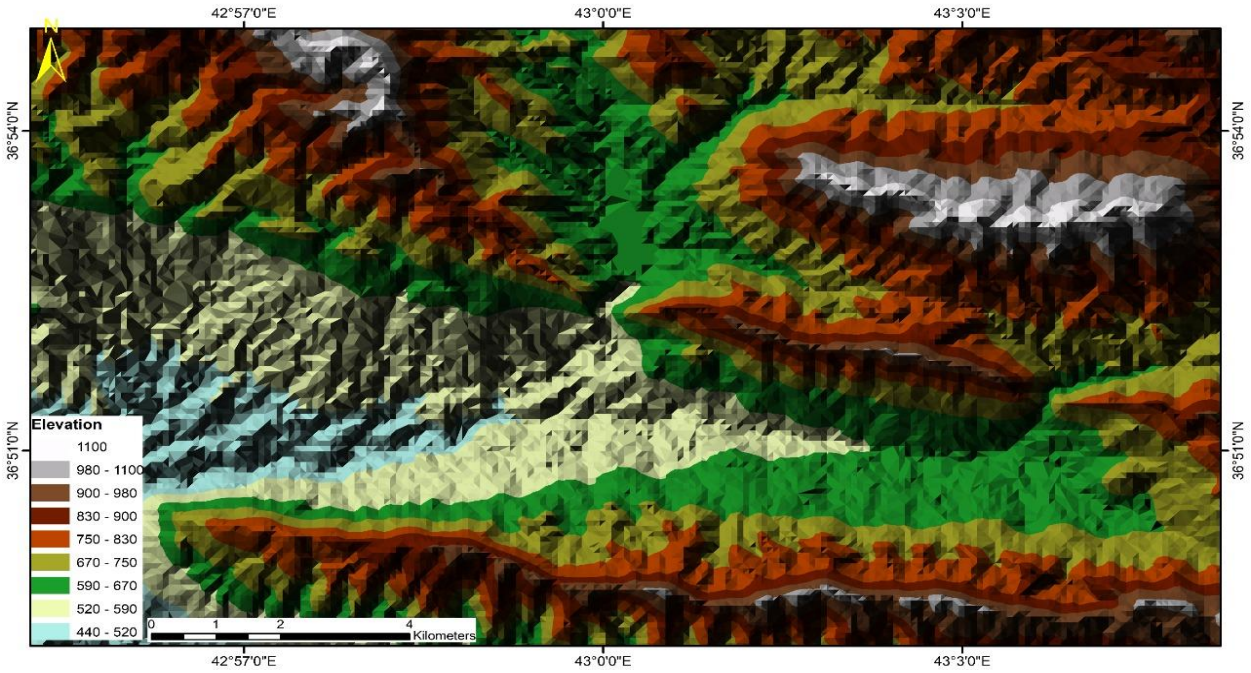
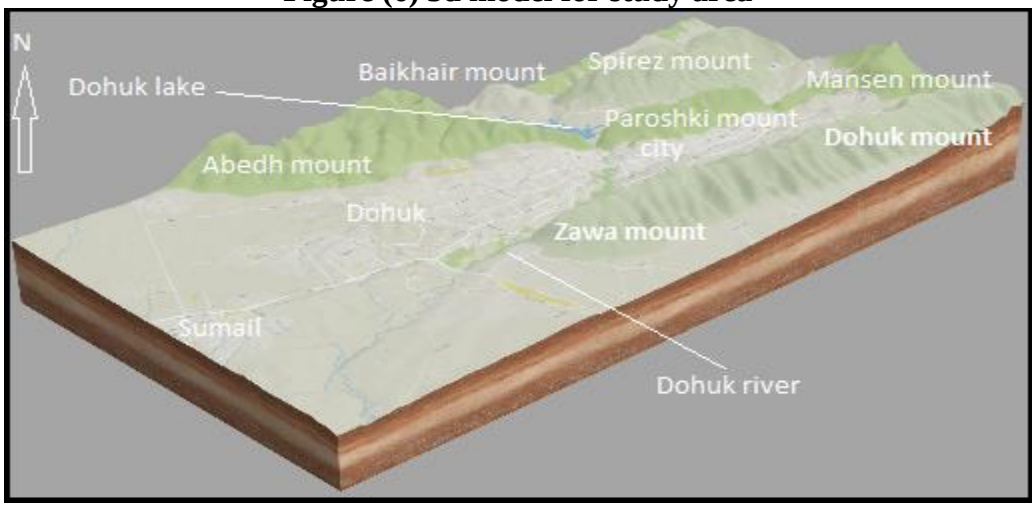


Figure (6) 3d model for study area



(https://3d-mapper.com/)

The slopes in the region vary from one geomorphic unit to another and range between 0-87.9° Figure (7) The urbanization of the city has included all land units without exception from the floodplains to the pediments and the mountains , the mountains themselves ,their slopes been cut and modified to be used as roads or houses etc. In 1967 the city with a slope ranging from between 0-25°, While in 1987 the

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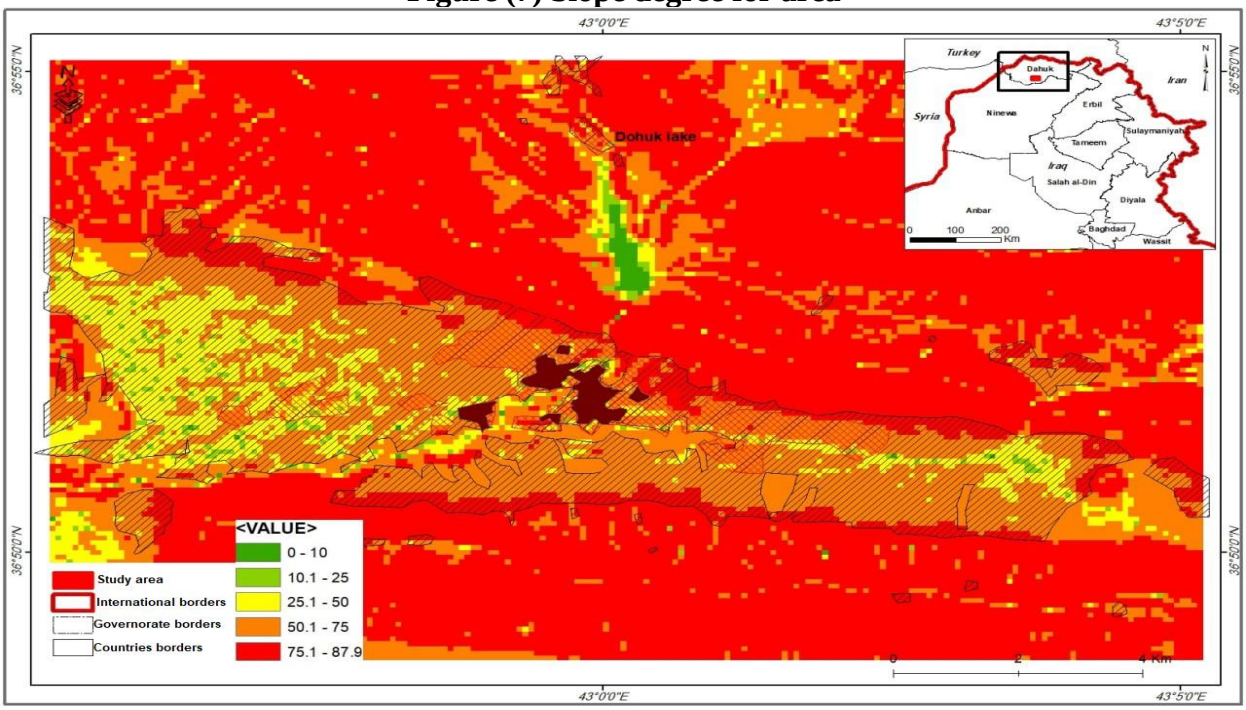
city's extension was on a slope ranging from 25 to 50°, and in 2022, the city's expansion was on a slope ranging from 50° - 87.9°, which means that the city with different uses is on the edge of the cliff, which means exposure to the risks of mass movement of different slope materials.

Figure (7) Slope degree for area



6. Discussion

6.1 Growth of Duhok city between (1967-2022):

The city of Dohuk continues to grow from its inception to the present day, as it is evident from the centralization of the city's growth between the northern (Bakhair) and southern (Dohuk)mountain ranges, relate with the landscape of the area on which it is built and there are many varied land units features in the region, which are concluded some physical characteristics such as the nature and characteristics of its rock formation, as well as the slope characteristics varies in the slopes as slope degree, aspect from one place to another and so on for the other physical characteristics of each area for each land units with its physical details.To detect the extension of the city and monitoring changing for its expansion and direction, the extension appears by comparing Three satellite images (1967,1987,2022) for the city and showing the gradual (spatial and temporal) growth of the city and its expansion are observed through these selected periods of the city Table (3) , figure (8).

Table (3) growth of Duhok city

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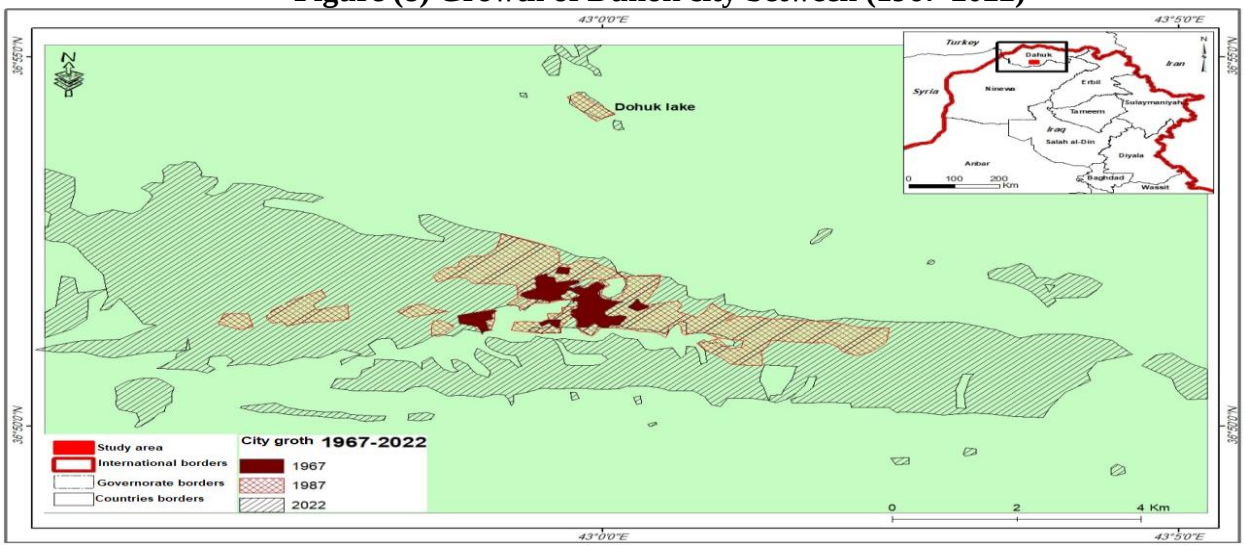
Year	Area(km^2)
1967	1.037741
1987	6.944
2022	41.646602

Figure (8) Growth of Duhok city between (1967-2022)



6.2 Overlay Geomorphic-unit with city growth

The city of Duhok extends over basic geomorphic units that are mainly different in their Elevation, slope and other characteristics, this extension is governed by the diversity of these geomorphic units. These geomorphic units include secondary land forms. These geomorphic units include the flood plain, Accumulation Glacis, Alluvial fan, Pediment, Mounts Figure (9). These geomorphic units which the city extends on it, with altitudes vary from 438 meters in the floodplain to 1136 meters in the mountains. The least elevation and area of the geomorphic units are the floodplains, whose height between (438 – 445m) and with area (2.9 km^2) in the region, while the Alluvial fans occupy the largest area (63.8 km^2) of the region, which is located at a height between (593.1 - 748.2m) Table (4).

Figure (9) Geomorphic units

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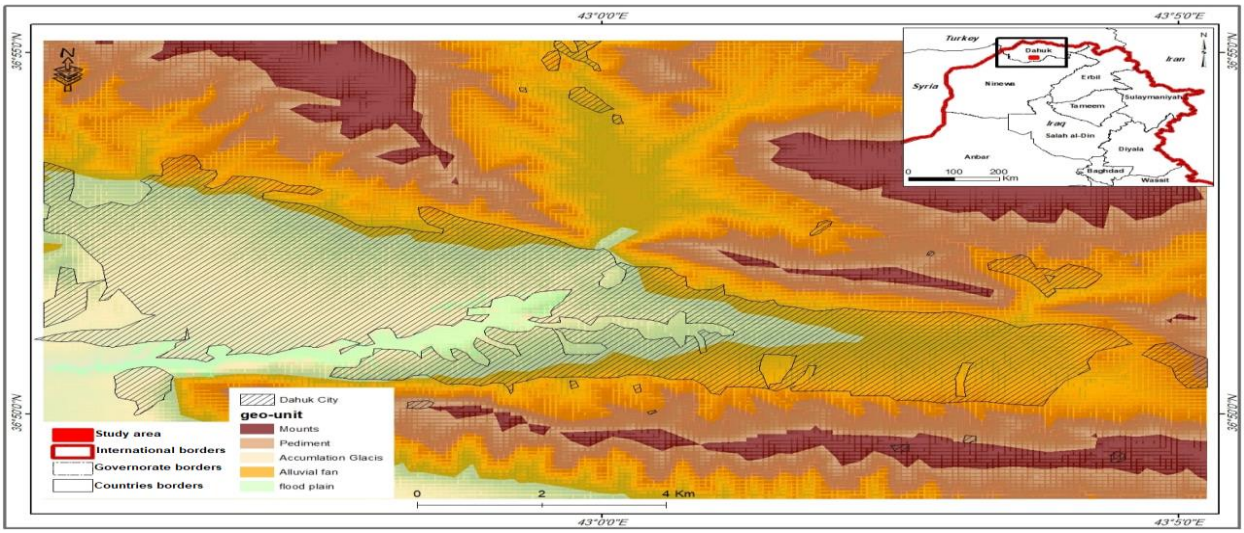

Table (4) Geomorphic-unit with its lithology, stratigraphy, elevation and area

Nu.	Geo-unit	Lithology	Stratigraphy	Elevation (m)	Area(km^2)
1	flood plain	Sand-silt-clay	Quaternary	438 - 445	2.9
2	Accumulation Glacis	Terraces - slope deposits: rock fragments-sand-silt	Quaternary	445.1 - 593.111	43.7
3	Alluvial fan	rock fragments	Quaternary	593.112-748.222	61.8
4	Pediment	Sandstone-siltstone-claystone-pebbles	Tertiary	748.223 - 825.778	48.3
5	Mounts	Limestone-dolostone-marl-sandstone	Cretaceous	825.779 - 1136	19.5
Total					176.2

The extension of the city in 1967 was limited to two geomorphic units, the floodplains, and the accumulative glacis, because these two units had a slight slope, and after that the city began to expand

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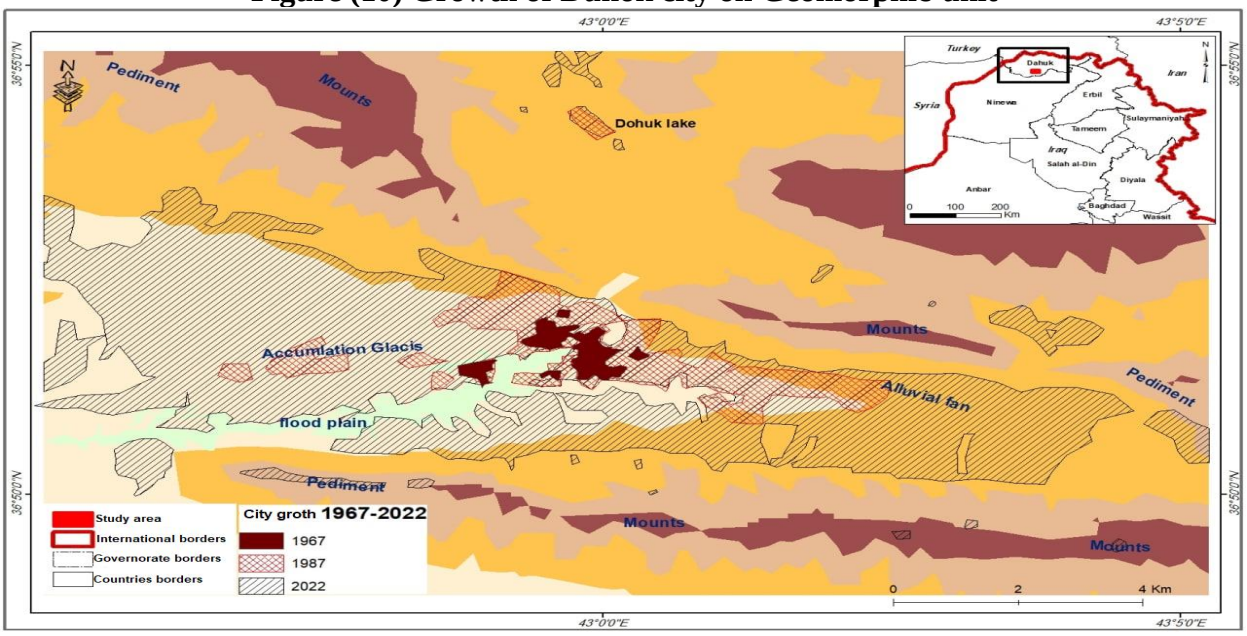
until it reached new geomorphic units in 1987, but in 2022 it included other new units, until that It reached the geomorphic units with higher elevations and slopes than its formers, which are the pediments and mountains. The need for new lands and different land uses results in the expansion of the city and the presence of mounts in the north (Baikhair mount) and (Dohuk mount) in the south and their coalescence in the east, which results in the expansion of the city towards the mountains in the north and south, the most attractive geomorphic unit for the city's uses currently is the pediment and a lesser extent the unit of the mountains figure (10) .

Figure (10) Growth of Duhok city on Geomorphic-unit



The unit of the pediment is characterized by the presence of slope deposits that have a little cohesion and composed of fragments of rock, sand and silt, which are disjointed and incoherent, and therefore urban expansion will be on such weak materials like this, In the end, the expansion of this geomorphic unit will be on the margin and bottom of the mountains, and sometimes it will spread through these mountains. The most appropriate direction for the expansion of the city without obstacles is the western side the city progress gradually from west towards Sumail and Misureek Township, this side, characterized with flat lands that attract the city's with their different uses for merely extending over it, the similar case for the north west part of the city, and the southern west part of the city by turning around the mountains of Duhok from the south, as the land is flat below Mount Duhok (Zawa) and suitable for city expansion figure (11) . As for the northern, southern and eastern sides of the city, there is an incursion of some critical sections of the city constructed on pediment to mountains units.

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Additionally, growth of these mountain towns has modified the drainage, figure (12), such that, when subdivisions are built, many minor geomorphic features are destroyed, increasing the likelihood of potentially hazardous geomorphic processes. Specifically, slope is graded for building. In addition, the covering of pervious surfaces with house footprints, concrete, roads, and parking lot surfaces has greatly decreased infiltration and increased surface runoff. Moreover, city infrastructure plays a role in altering the environment. Early mountain roads, although less frequently used, are still present and provide narrow regions of slope modification and impervious surfaces. The present road in the region with high amounts of mass movement increases these risk factors. The high traffic flow on this corridor also contributes external heat and vibrations to the soil, compromising slope stability [6].

figure (11) GE image show Dohuk city extension on pediments with lesser on mountains

Figure (12) Bing space image depict west basins in way of Dohuk future city extension, notice basin1 its one of dohuk river tributaries its head in Sumail district while basin2 its head with Misureak district, the four basins likely for Dohuk city in future.

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As a result of the expansion of the city in different directions and as previously for the morphological situation of the city, which is formed according to the geomorphic situation so there are many directions for city growth figure (13) white arrows indicate the growth of the city towards the mount unit within the axes of the north, east and south of the city and also within the SW axis of the city turning around Zawa Mount towards Zawa district represented with flat lands, the west is divided into two parts, the First axis towards the northwest, an area that is flat and suitable for the expansion of the city and the second axis is the southwestern axis of The city towards the Sumail and Misureak districts.

Figure (13) Bing space image show aspects city expansion: White arrows expansion of city towards mounts, yellow to S and turning around Zawa mount,green to NW red across W Sumail and basins

expansion of the city can be expressed by the urban tide or urban flood (tide) and the decline of the natural landforms in favor of the anthropogenic landform and this urban tide and urban expansion at the expense of land units of landform origin and be a land system is a natural environment modified by human action and even if the urban fabric of the city covered the natural landforms, inevitably the underlying geomorphic processes and which of the landforms will have an impact on Urban fabric and with a particular dynamism and a certain extent for each process that this modification of the landform by the city will have a corresponding effect on the city by the geomorphic processes, so Urban Geomorphology and Sustainability' provides an overview of the key landscapes and common themes in urban geomorphology (centered upon urban rivers, karst landscapes and the weathering of buildings) thus, urban geomorphology is defined geographically confined to areas of concentrated urbanization, where the natural environment is anthropogenically modified and where natural processes modify anthropogenic structures. A need for sustainable urban geomorphology [7].

Growth of the city, for example, on the northern side of it, will lead to the extension of the city to areas subject to karst processes, there is also a charsteen cave (Geosite) photo (1), also in the northern side of the city near Lake Duhok, the expansion of the city from the unit of the pediment towards the unit of the mountains photo (2) the white arrows indicate the presence of a barrier of plants, which is a barrier to repel the slopes that protect the buildings below them from the mass movement, while the red arrows

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indicate the direct urban expansion from the unit of pediment to the unit of mountains without the presence of plants. A dramatic quickly changing the northern part witnessed it appeared by a comparison of two satellite images of the northern portion of the city figure (13-A) in 2004. There are a clear preparing and cutting slopes processes to create residential use, while figure (13-B) represents a satellite image after 17 years for the same area, showing the urban growth of buildings and their transition from the pediments to the mountains unit, with the presence of zigzag roads that cross the high slopes in the mountains.

photo (1) Charsteen cave

(http://duhoktourism.org/place/charsteen-cave)

photo (2) Northern part of Dohuk town, white arrows indicating vegetation barriers on the slopes while red arrows indicate expansion of the city towards mounts

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(22\3\2022)

So a sustainable plan wanted for Dohuk city planning take in account many aspects among its: a sustainable urban drainage system (SUDS) [8] for Dohuk River and four basins in west, a charsteen cave as geosites which consider Primary geosites have geological and/or geomorphological features. Either natural or artificial and generally permanently exposed. Within a delimited area and of some significance for their scientific, educational or interpretative value; they range from quarries and natural cliffs to mines and caves. They can be refined on the nature of the localities at which geotouristic activities [9]. Dohuk City have Many natural landforms, and landscapes are related to the foundation and to the history of the city. During the last three thousand years. Several landforms have been remodeled. Created or vanished due to human activity and natural processes. They nowadays represent the morphological consequences that both man and nature have marked in the territory [10]. Dohuk City changing trends accompanied with Significant modern land-cover changes that impact on the geomorphic system include those related to agricultural development, but also include those caused by developments in mining, industry, urbanization and tourism [11].

Figure (13) GE images comparisons for northern part of city (A) 10-2004 urban expansion for the north section of city south dohuk lake the sprawl within pediments while in south east towards the mounts the cutting and preparing processes clear for housing (B) 2-2021 the same area show an obvious urban growth from crowded pediment to mount units with zigzag roads.

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6. **Conclusions**

Dohuk city stand upon 12 various, heterogeneous formation and sedimentation which have different response to geomorphic processes, with six Geomorphic units, the highest unit area is Alluvial fan 63.84 km^2, lowest unit area is flood plain 2.94 km^2. the city expansion as 1967 1.0 km^2, 1987 6.94 km^2, 2022 41.64 km^2. the extension of the city in 1967 was limited for two geomorphic units, the floodplains and the accumulative glacis, in 1987, in addition to previous units, the city extended on a new geomorphic units, which is the fluvial fans, and in 2022, the city expanded to the previous geomorphic units, in addition to its extension on geomorphic units with higher elevations and slopes than its formers, which are the pediments and mountains. Dohuk city need for sustainable plan planning take in account many aspects among its: a sustainable urban drainage system (SUDS) for Dohuk river and four basins in west,

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a charsteen cave as geosites, Dohuk city have Many natural landforms and landscapes are related to the foundation and to the history of the city. they represent nowadays the morphological consequences that both man and nature have marked in the territory.

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الجيومورفولوجيا الحضرية لمدينة دهوك

الملخص:

كانت مساحة مدينة دهوك في 1967 1كم^2 , وتوسعت بعد ذلك الى ان وصلت الى 6.94 كم^2 في عام 1987, ثم 41.64 كم^2 في عام 2022, تمتد على 12 تكوين وترسيبات مختلفة وغير متجانسة ذات استجابات متباينة للعمليات الجيومورفية، اذ تشكل رواسب المنحدر أعلى مساحة 46.9 كم^2، وأدنى مساحة لتكوين هو عليجي 2.6 كم^2، تحيط الجبال المدينة من جميع الاتجاهات باستثناء الغرب، جبل بيخير من الشمال، وجبل دهوك من الجنوب، ومام سين من الشرق، وارتفاع المنطقة بين 1100 - 440 م، درجة الانحدار بين 0 - 87.9°. هناك 6 وحدات جيومورفية، أعلى وحدة مساحة هي المروحة الفيضية 63.84 كم^2، وأدناها مساحة هي السهل الفيضي 2.94 كم^2. اقتصر امتداد المدينة في عام 1967 على وحدتين جيومورفيتين هما السهول الفيضية وسهول اوحادورات تراكمية، اما في عام 1987 امتدت المدينة الى وحدات جيومورفية جديدة هي المراوح الفيضية، وفي عام 2022 تخطت المدينة الوحدات الجيومورفية السابقة إلى وحدات ذات ارتفاعات ومنحدرات اعلى من سابقاتها، هي اقدام الجبال والجبال. أخيرا، يمكن أخذ نتائج دراسات الجيومورفولوجيا الحضرية في الاعتبار في سياق التخطيط العلمي المنهجي والشامل بدلا من التوسع العشوائي وغير المدروس للمدينة.

الباحثين

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الكلمات المفتاحية : مدينة دهوك ،الحضر

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