International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 34 العدد
Part 1 المجلد
April 2024 ابريل

تم استلام الورقة بتاريخ: 26/ 3/2024م وتم نشرها على الموقع بتاريخ: 20/ 4/2024م

The impact of earth topography on urban planning using remote sensing techniques and geographic information systems

www.doi.org/10.62341/wtwa2520

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Abstract

This research aimed to show case how remote sensing technologies and geographic information systems can be utilized to identify issues arising from the Earths terrain. The study focused on the water accumulation during post rainfall, in the entrance of Tripoli specifically in the Tajoura (bivy) area. This water buildup often leads to traffic congestion resulting in road closures and rising water levels that sometimes reach building entrances. Such circumstances affect the planning of the area and its neighboring regions. Satellite images sourced from the US geological survey website were employed to analyze features of the study area and present them through digital maps illustrating surface topographical characteristics, like area shape, land slopes, water flow patterns, etc. Various analyses were conducted including assessments, hydrological studies, understanding structures and soil types within the study region with an objective to pinpoint core issues related to this phenomenon and explore potential solutions.

Keywords: Remote sensing, geographic information systems, urban planning, topography, water buildup.

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تأثير طبوغرافية الأرض على تخطيط المدن بإستخدام تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية

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الملخص

تهدف هذه الدراسة لإظهار إمكانيات تقنيتي الاستشعار عن بعد ونظم المعلومات الجغرافية في تحديد المشاكل التي تسببها طبوغرافية الأرض، حيث تم التركيز علي المياه التي تتجمع بشكل كبير أثناء وبعد سقوط الأمطار في مدخل طرابلس الشرقي وبالتحديد منطقة تاجوراء (البيفي) والتي تسبب اختناقات مرورية شديدة مما يجعل الطريق مقفلة تماماً ويرتفع منسوب المياه حتى يصل أحياناً إلى أعتاب المباني القريبة، الأمر الذي من شأنه أن يؤثر علي التخطيط العام للمنطقة والمناطق المجاورة،وتم استخدام مرئيات الأقمار الصناعية المتحصل عليها من موقع هيئة المسح الجيولوجي الأمريكية، من أجل استنباط وتحليل بعض الخصائص التضاريسية لمنطقة الدراسة، وتمثيلها على شكل خرائط رقمية تبين الظاهرات الطبوغرافية السطحية كالشكل العام للمنطقة ومستويات انحدار الأرض وتحليل حركة المياه وغيرها، وذلك عن طريق إجراء التحليلات اللازمة كالتحليل الطبوغرافي والتحليل الهيدرولوجي ومعرفة التركيب الجيولوجي ونوع التربة لمنطقة الدراسة، للوصل إلى تحديد المشاكل الأساسية لهذه الظاهرة وإمكانية وضع الحلول اللازمة لها.

الكلمات المفتاحية: الاستشعار عن بعد، نظم المعلومات الجغرافية، تخطيط المدن، طبوغرافية، تجمع المياه.

Introduction

Water pooling from rainfall can be a common problem in many areas, posing a threat to infrastructure and public health. Therefore, addressing this issue in the Tagoura area was crucial. Indeed, Tagoura suffers from problems related to water pooling due to

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rainfall and has a weak sewage system. This water pooling can lead to significant health and environmental problems, including the spread of infectious diseases and contamination of groundwater, remote sensing data was obtained through the US Geological Survey website (USGS), and the study was conducted using ArcGIS 10.8 software.

Based on this, the elements of the area's study are as follows:

- Geographical location study: This involves understanding the geographical location of the area under study, which helps in identifying its position and neighboring regions.
- Surface features and topography study: This includes recognizing contour lines, surface slopes and their directions, and hill shades to understand the nature of the land and surface curvature.
- Hydrological analysis study: This entails understanding the hydrological aspects of the studied area, such as the flow direction, areas of water accumulation, the streams in the area and their strength, as well as the basins in the Tagoura region.
- Geological formations and soil type study: This involves studying the geological formations and soil types in the studied area to determine the soil's suitability for reforms and the possibility of problem solving.

The geographical location:

The Tagoura region is located in the northwestern part of Libya, on the shores of the Mediterranean Sea. It is considered one of the largest suburbs of the Libyan capital, Tripoli. It is bordered to the west by the Souq Al Jumaa area, to the east by the Castelverde area, to the north by the Mediterranean Sea, and to the south by the Rabie valley and the Eastern valley. It extends between longitude lines (15’13°- 30’13°) east and latitude lines (40’32° - 00’33°) north as shown in the figure1.

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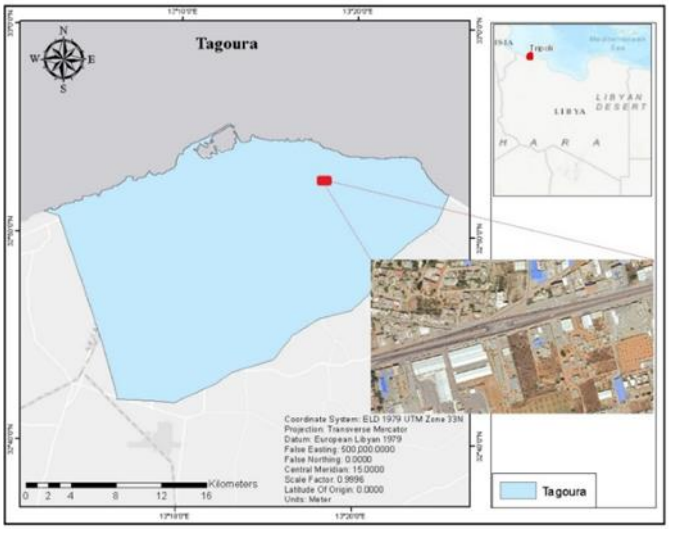

Figure 1. Study area, (USGS 2024), (ArcGIS 10.8)

The research problem of the study:

Within the study area, there is a critical point where water accumulates when it rains, and this issue is considered a hindrance to development. The research problem can be summarized by the following questions:

1) What is the topography of the study area, including the analysis of contour lines and surface features?
2) The natural characteristics that lead to water accumulation at this point.
3) The nature of spatial location of the phenomenon.

The importance of the study:

The following points sum up the importance of this research:

1) Determining the extent and volume of water accumulation at this point.
2) Studying the streams and basins at this point.
3) Assisting decision-makers in finding appropriate solutions.

The objectives of the study:

1) Identifying the basins located in this point.

2) Pointing out the distribution of water at this point and its impact on the soil and vegetation cover in the area.
3) Finding suitable solutions for water distribution from the critical point.

The methodology of the study:
The research uses the descriptive method, which involves describing the studied phenomenon based on various sources and references. This includes gathering information and data from books, scientific reports, sources, references, and research studies.

First: Topographic analysis of the studied area:
Topography is a branch of geography that deals with the study and measurement of the Earth's surface, its terrain, natural landforms, and geomorphological changes that occur on the surface.
Topography utilizes different tools and techniques for mapping, imaging the Earth, measuring distances and heights, and determining geographical locations. These techniques include the use of GPS data and remote sensing data, such as aerial imagery, satellite imagery, terrestrial laser scanning, and geological maps. In fact, many fields, including urban planning, infrastructure, agriculture, natural resource management, urban areas, and urban development, utilize topography.
Topographic data analysis plays a crucial role in terrain analysis as it helps in understanding the physical features and natural phenomena of a particular area. It involves collecting, interpreting, and analyzing data related to elevation, contour lines, and other physical features of the area. This information is essential for various applications such as urban planning, environmental assessments, and natural disaster management. Through topographic data analysis, scientists and researchers can gain insights into the natural processes occurring in a specific area, which can be useful in predicting potential risks and mitigating their severity (Sharaf, 1971).

- **Contour lines:**

Contour lines, also known as level lines, are lines that connect points of equal elevation on the Earth's surface. They are used in the fields of geology, geography, and civil engineering to represent the natural terrain of an area effectively.

Generally, we use contour lines for several purposes, including:

Recognition of elevations: Contour lines depict differences in elevation between different areas. Each line represents a constant elevation above sea level.

Identification of geographic units: Contour lines can be used to identify the geographic behavior of groundwater or mountainous terrains.

Analysis of slopes: Contour directions and distances between them can be analyzed to understand the slopes and gradients in terrains.

Design of roads and railways: They are used in transportation engineering to design roads and pathways that fit the terrain.

Infrastructure planning: Contour lines are used to identify suitable areas for infrastructure such as buildings and sewage networks (Gouda, 2005).

- **Contour Maps:**

Contour maps are a type of topographic map that displays elevations and terrains using lines of equal elevation, known as contour lines. These maps use curved lines that connect points of the same elevation on the Earth's surface. In the previous map, contour lines are divided into 10 lines with a contour interval of 10 meters between each line. It is evident from the critical point that a contour line of zero elevation emerges in the area, indicating a depression in the land at this point. In the studied area, as we move southward, we observe an elevation in the surface level of the land.

The Tagoura region, for instance, is enclosed within the contour line of 10 meters above sea level, surrounded by elevations delineated by the contour line of 20 meters. This illustrates one of the reasons for water accumulation in the Tagoura area, as it is situated in a lower area compared to its surroundings, as shown in the figure 2.

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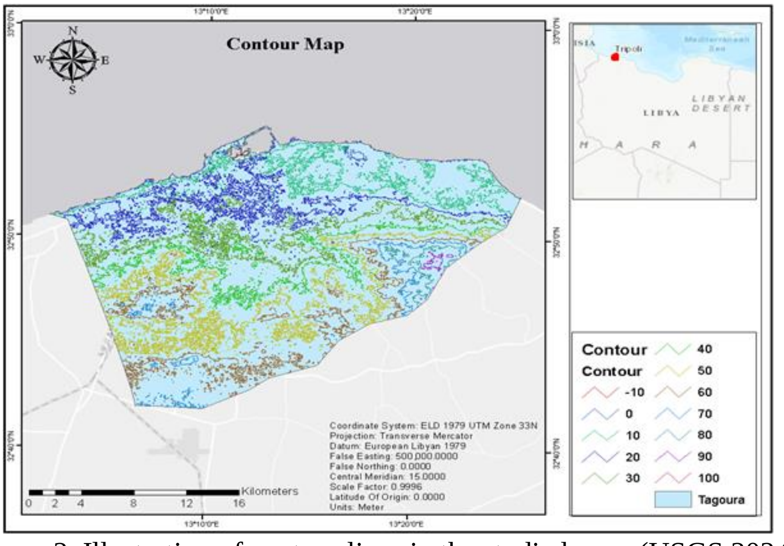

Figure 2. Illustration of contour lines in the studied area, (USGS 2024), (ArcGIS 10.8)

- **Slope:**

Slope is a term used in geography and earth sciences to refer to the downward direction or natural inclination of the earth's surface. Slope can be positive or negative and is related to the inclination or direction in which the surface moves. Terms such as "slope angle" are used to describe the degree of inclination or the direction in which the surface tilts. It can be categorized into:

Positive Slope (Ascending): This occurs when the natural direction of the surface is upward or ascending. This can result from the formation of mountains or terrain inclined towards elevation.

Negative Slope (descending): This occurs when the natural direction of the surface is downward or descending. This can result from the presence of valleys, ravines, or descending plains (Gouda, 2005).

According to the previous map, we find that the slope of the studied area is located between 1 and 5 degrees. This means that the slope is very weak, almost flat, in that area, indicating the reason for water accumulation within the region, as shown in the figure 3.

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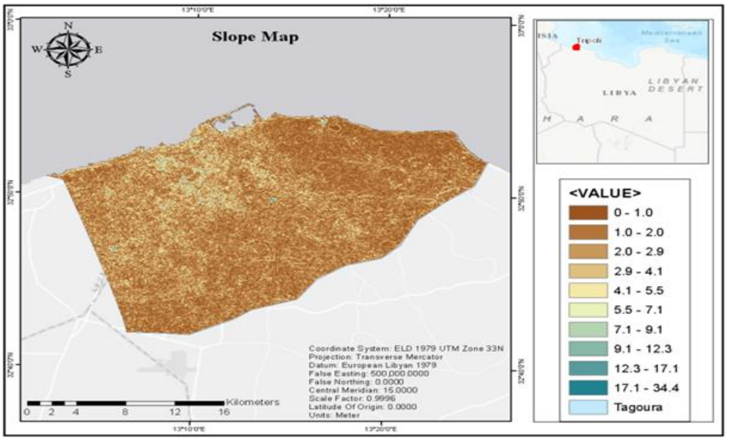

Figure 3. Illustration of slopes in the studied area**,** (USGS 2024), (ArcGIS 10.8)

- **Slope Directions (Aspects):**

Slope Directions (Surface Aspects): In Geographic Information Systems (GIS), the term "ASPECT" refers to the direction of the slope or the geographical inclination of the surface. The aspect of the slope is measured as an angle between the direction of the sun's rays and the horizontal direction of the surface, usually expressed in degrees.

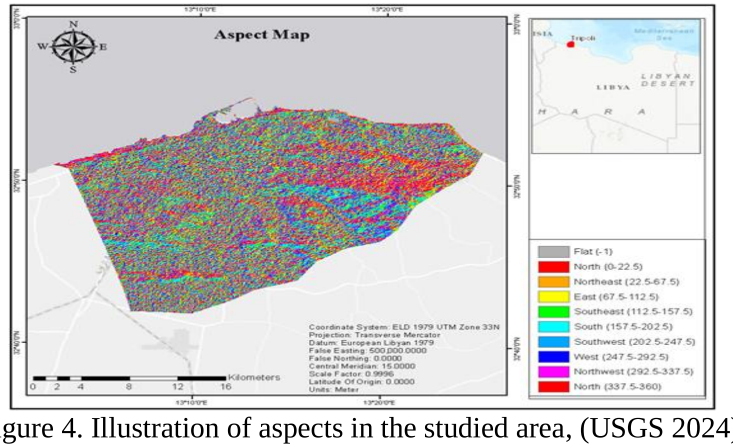

Figure 4. Illustration of aspects in the studied area, (USGS 2024), (ArcGIS 10.8)

From the previous map, the studied area is divided into 10 aspects, with each aspect indicating its direction. The flat surface dominates the study area, along with some sloping areas. The slopes of these areas tend to incline towards the west and south, while other slopes toward the north. This indicates the presence of some small hills around the studied area, making water accumulation and concentration in the Tagoura area easy,as shown in the figure 4.

- **Hill shade:**

The hill shade function provides a three-dimensional representation with a grayscale gradient for the terrain surface, considering the relative position of the sun and taking shadowing into account by default. The grayscale shading is used to display the shaded elevation model. For instance, the following images display the elevation model using the traditional default hill hade method, followed by the multi-directional hill hade method.

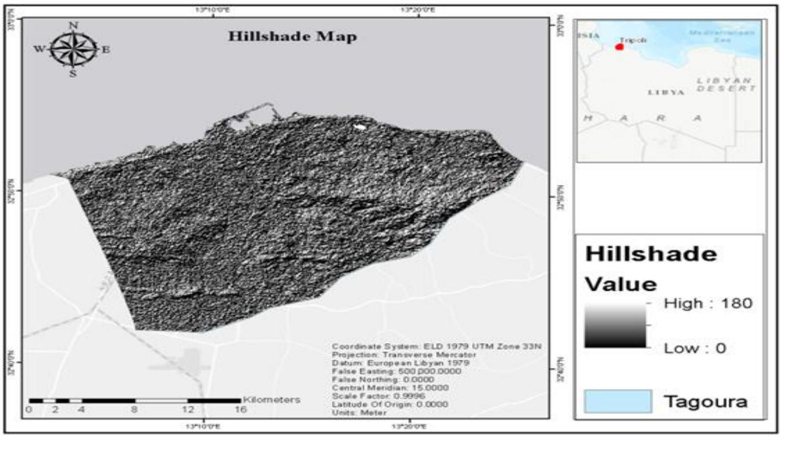

Figure 5. Illustration of shades in the studied area, (USGS 2024), (ArcGIS 10.8)

According to the Terrain Shadow Map, which illuminates the ground from multiple angles, shadows shape the earth's surface, highlighting elevations, lowlands, and flat lands. According to the previous map, it is evident that the studied area is a semi-flat region situated between elevated areas without proper drainage channels.

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This leads to rainwater accumulation in that area, as shown in the figure 5.

- **Curvatures:**

Curved land formations refer to the terrain and natural features that show curves and slopes on the earth's surface. These formations can result from various geological and geomorphological factors, such as geological folds, valleys, hills, and mountains,as shown in the figure 6.

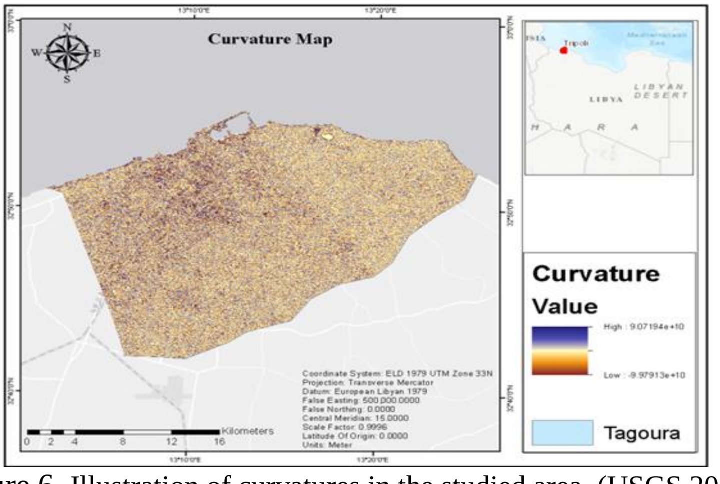

Figure 6. Illustration of curvatures in the studied area, (USGS 2024), (ArcGIS 10.8)

- **Mountains and mountain ranges:** Mountains and mountain ranges often represent naturally curved formations, formed as a result of tectonic forces associated with the movement of tectonic plates.
- **Valleys and canyons:** Valleys and canyons are curved areas formed by factors such as the impact of rivers and natural erosion.
- **Hills and heights:** Hills and heights can generally be slightly curved areas, and they can result from various factors such as erosion, wind, and water.

- **Streams**: Streams are deep curved canyons typically formed by the influence of rivers and water currents.
- **Plains:** Plains may be more horizontally oriented areas, but they may also contain slightly curved formations.

Secondly: Hydrological analysis:

Hydrological analysis is the process of studying and evaluating the hydrological behavior of rivers, streams, and watersheds. This analysis aims to understand and analyze changes in water flows and water distribution in the environment (Al-Jedidi, 2002).

- **Flow direction:**

Flow direction refers to the direction in which water moves on the earth's surface or within a water system. In hydrological or geographical analysis, flow direction indicates the path along which water descends from a higher area to a lower one. In fact, water lines or contour lines on maps can determine the flow direction (Hassan Mohammed Al-Jedidi, 2002, p. 268). In the studied area, it is observed that there is stagnation in the movement of water, indicating the reason for water accumulation and its failure to disperse in the area, as shown in the figure7.

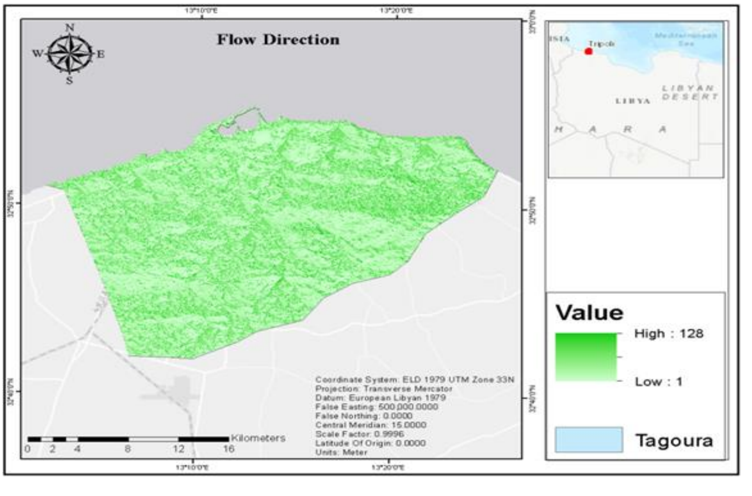

Figure 7. Illustration of water flow direction in the studied area, (USGS 2024), (ArcGIS 10.8)

- **Water flow accumulation areas:**

A map of water flow accumulation areas illustrates the areas where water collects and converges into a specific water system, such as a river or lake. These areas are referred to as water basins. Hence, the map shows the pathways through which water flows towards the gathering points. (Al-Jedidi, 2002).

According to the previous map, we find that the studied area is located within the areas where water flows due to its low elevation. This is one of the reasons that led to the accumulation of rainwater in that area, causing numerous problems. Therefore, it is important to take measures to effectively drain the water and avoid its accumulation to reduce potential environmental and health problems,as shown in the figure 8.

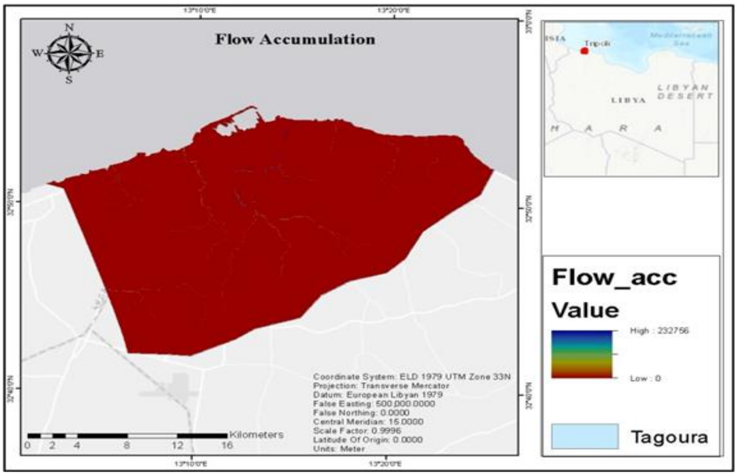

Figure 8. Illustration of water flow accumulation areas in the studied area, (USGS 2024), (ArcGIS 10.8)

Stream order:

Stream order is based on a concept known as the hydrological ordering system. We use this system to classify and arrange natural drainage systems, such as rivers and streams, using a hierarchical structure that illustrates how the sub-branches connect to the main sections. Indeed, we use this system to facilitate the understanding

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of the hydrological organization of rainfall and its collection and discharge. In addition, we order streams according to the number of sub-branches that join them. In fact, while main streams have a higher order, sub-branches have a lower order.

We remark that the studied area is located in a second-order stream. These streams are the ones that carry water only during the rainy season and collect water due to their poor drainage. Naturally, this explains the problem of water accumulation in the studied area,as shown in the figure9.

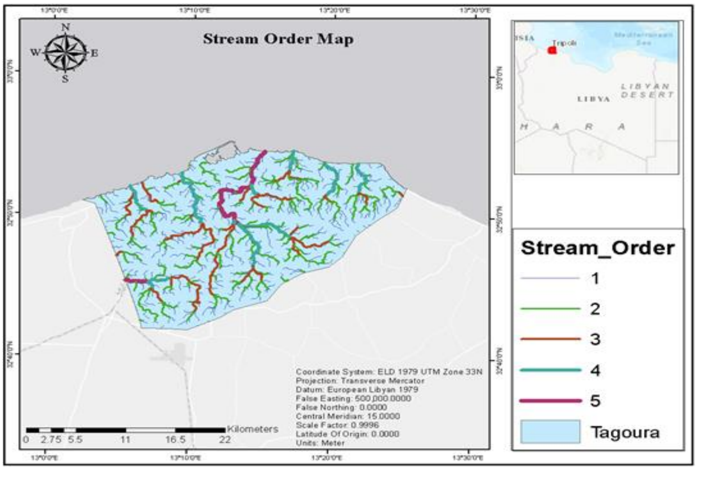

Figure 9. Illustration of stream order in the studied area, (USGS 2024), (ArcGIS 10.8)

- **Basins:**

The term "basins" refers to areas where surface water accumulates, forming a complete water system. Basins can be diverse and include a wide range of aquatic environments (Al-Jedidi, 2002).

The studied area is located within one of the 450 basins in Tripoli. These basins play a crucial role in providing water for plants, animals, and humans. Additionally, they contribute to regulating the region's climate and preserving biodiversity. However, proper management of basins is necessary to avoid pollution and

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desertification problems and to ensure the sustainability of water resources in the area,as shown in the figure 10.

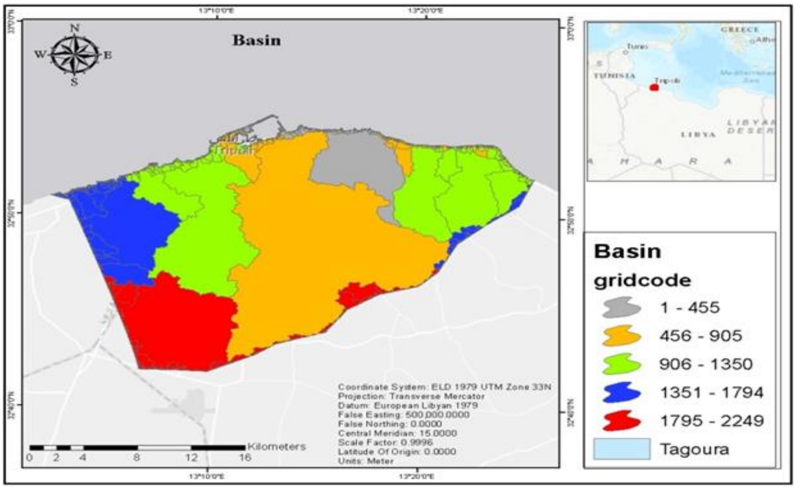

Figure 10. Illustration of basins and the biggest basin in the studied area, (USGS 2024), (ArcGIS 10.8)

- **Basins and stream order:**

Streams and their basins form a complex drainage system where water flows from highlands to lowlands through streams and gathers in a basin. In the studied area, many basins and streams play a crucial role in distributing, storing, and draining water. In fact, it is important to understand these basins and streams in order to improve water resource management and protect the aquatic environment.

Regarding basins, the Tagoura region includes small lakes, ponds, marshes, and small rivers. These water features serve as sources of local plant and animal life and contribute to regulating the region's climate.

As for the streams, there is a network of small and medium-sized streams that drain water towards lowlands. The region is situated on a group of second-order streams, which are considered to carry water only during periods of rainfall, as shown in the figure 11.

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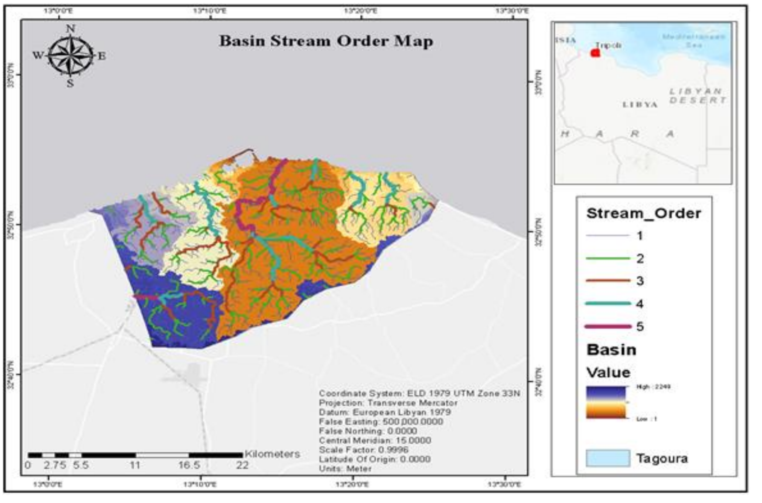

Figure 11. Illustration of streams order and the basins' number in the studied area, (USGS 2024), (ArcGIS 10.8)

Thirdly: Geological structure and soil type:

In the studied area, the geological structure and soil type are two important factors that cause the problem of ineffective rainwater drainage. In fact, there are many reasons that illustrate the importance of these factors, which are:

- **Soil absorption:**

The soil in this area is non-absorbent. Consequently, heavy rains lead to rapid water accumulation. The soil in the studied area is dry with cohesive lime materials. In fact, it tends to be ineffective at absorbing water efficiently due to its non-porous nature. In addition, it acts as a barrier to rainwater drainage. Therefore, rainwater that falls on this soil accumulates on the surface instead of being absorbed. This leads to the formation of water ponds and their accumulation in low-lying areas, as shown in the figure 12.

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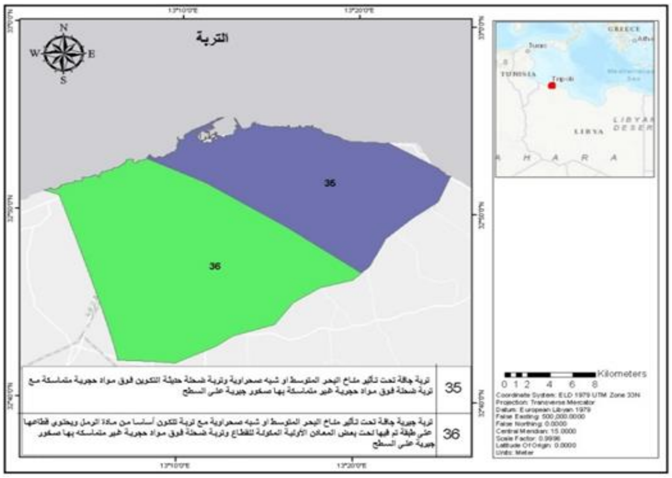

Figure 12. Illustration of the soil in the studied area, (USGS 2024), (ArcGIS 10.8)

- **Geological structure:**

The geological structure in the studied area is from the Pleistocene epoch. In fact, the Pleistocene epoch is a period in recent geological history that occurred after the Miocene epoch and before the Holocene epoch. It extends approximately from 5.3 million ago years to around 2.6 million years ago.

The geological structure includes sedimentary marine and terrestrial rock. These sedimentary rock formations comprise layers deposited during the Pleistocene epoch due to factors such as weathering, marine transgression and regression, and riverine and marine sedimentation. They consist of materials such as sand, clay, gravel, limestone, and chalk. In fact, these are some reasons explaining the occurrence of the problem of ineffective rainwater drainage in the studied area, as shown in the figure 13.

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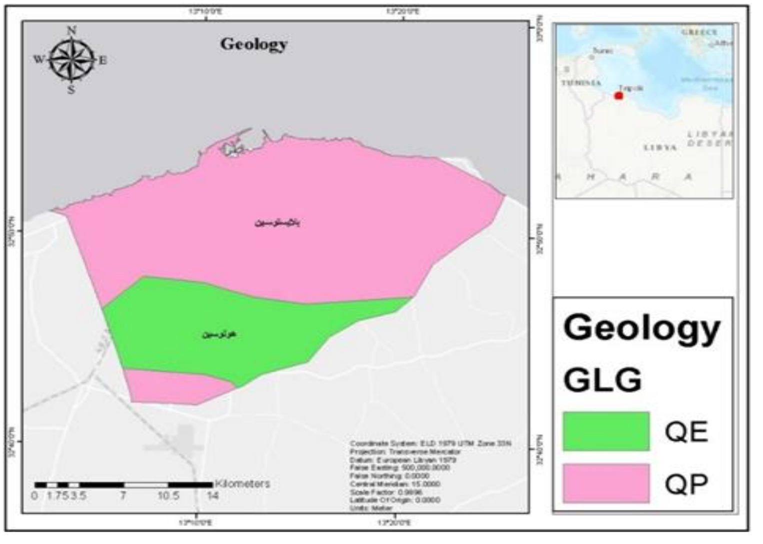

Figure13. Illustration of the geography structure in the studied area, (USGS 2024), (ArcGIS 10.8)

Conclusions

1- It was found that the study areawhile studying the topography and nature of the land in the studied area, including contours, elevation and their directions, terrain shades, and land curvature, it was found that the area is situated in a low-lying position compared to its surroundings. This was directly evident when studying the terrain shades, revealing that the area is located amidst a cluster of hills, indicating that it is a water accumulation area for its surroundings. Similarly, when studying the curvature of the area, we found that the land has gentle slopes, which do not facilitate water drainage. As revealed by the contour map, the land is situated at an elevation of 10 meters, surrounded by elevations of 20 meters.

2- Hydrological analysis of the land:Based on the flow direction map and areas of water accumulation, our hydrological analysis revealed that the studied area lies in a location with a low discharge ratio. **A**dditionally, regarding the basins and the order of streams, we concluded that the studied area serves as a drainage basin for the surrounding areas due to its lower elevation compared to its surroundings. Moreover, the stream order was determined to be within

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the second-order stream category, indicating weak drainage capabilities.

The geological structure: The studied area is part of the coastal plain of Tripoli, which is principally composed of many layered sedimentary deposits formed over long periods of time. In fact, over time, the deposition of clayey, sandy, and gravelly materials has accumulated layers of clay, gravel, and sand in these sedimentary deposits. Indeed, all of these materials have poor water drainage properties.

Remote sensing data and geographic information systems programs are considered complementary to each other and are considered modern methods that help in conducting this type of studies and completing the work in the shortest time.

Digital maps of the study area were created showing its natural characteristics, land topography, geological structure, flow direction, valley ranks, knowledge of soil type, and the possibility of making amendments to it in the future.

Recommendations and solutions

1-Improving infrastructure: There is a need to develop and enhance infrastructure for water drainage, including the construction of sewage channels and waterways, as well as regular cleaning and maintenance.

2-Using sustainable drainage techniques: We must utilize sustainable environmental techniques, such as rain gardens and green areas, to absorb water and alleviate pressure on the public drainage system.

3-Utilizing water diversion barriers: We need to use barriers such as industrial or natural barriers to divert water away from areas prone to water accumulation.

3-Constructing dams and drainage basins: Constructing barrages and drainage basins in low-lying areas to collect water and prevent it from seeping into residential areas can be an effective solution to resolve the water issue.

4-Using Optimally terrain: Terrain design helps in directing water away by altering water pathways, which may be a good solution for the water problem in the Tagoura region.

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